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EDUCATIONAL PREPARATION FOR CREATIVE TECHNICAL ENGINEERING LEADERSHIP *

More Emphasis on Scientific Thinking

By R. E. DOHERTY

Dean, Yale School of Engineering

In drawing before you now the old thought which every novice in educational work must sooner or later propose, and which is also urged by those practicing engineers who mean to be educationally helpful, I fully realize that my job is a precarious one; for there is not a teacher among you who does not try to develop scientific thinking in the student, as far as this seems possible in view of the limited allotment of time, and of the subject matter to be covered. However, I am moved to make an appeal to you, because from personal observation of many engineering graduates in practice, I am convinced that scientific habits of thought are not developed at college to the extent they should be.

There is a crying need for men with such habits of thought. They are needed to solve the internal problems of technical engineering and engineering management in industry. Moreover, if the difficult and deep-seated external problems are to be solved, growing out of the relation between technological progress on the one hand, and a balanced, healthy social structure on the other, it will be because more constructive thinkers are available than there are now. Indeed, in a still wider sweep, if Western Civilization itself is not to go the way of all its predecessors, as Oswald Spengler says it must, it will be likewise because there are enough sound and active thinkers in all professions to give some direction to destiny, by making effective use of the great store of scientific knowledge which this civilization possesses, but which its predecessors did not. Scientific knowledge provides foresight only when it is properly used, and such use requires constructive thought.

The engineering profession has, in all of these problems, a peculiar responsibility. It has responsibility naturally to carry ahead technological progress; to pull into efficient gear the present disjointed machinery of industry and business, which condition its technology has largely created; and it has responsibility to help

* Presented at meeting, New England Section, S. P. E. E., Orono, Maine, Oct. 8, 1932.

keep it in gear as new technological advances tend to throw it out. All professions, of course, have heavy responsibility, but engineering especially.

As a final introductory word, it seems proper that I should outline the point of view from which my analysis has been made, so that you can accordingly appraise the conclusions. This viewpoint, I must confess, is not altogether competent. It is competent, I believe, as regards a fair estimate of the product of engineering education, an evaluation of existing educational objectives, and, at least to a moderate extent, the critical examination of methods and curricula in graduate work. On the other hand, it is less competent, by reason of insufficient first hand experience, as regards *method* in undergraduate work. As a basis for this point of view, it has been my privilege in a large manufacturing industry to study, at close range and over a period of years, both the educational attainments and the professional performance of large numbers of engineering graduates and post-graduates, representing practically every engineering college in the country. In such an industry the range of engineering activity covers practically the whole gamut—from the technical clerk to the creative genius; from the isolated specialist to the executive. In teaching and in directing with a free hand the educational activities of these graduates, I had opportunity to learn something regarding method of handling graduate work. However, I have had, as yet, practically no first hand experience in undergraduate teaching. In this my knowledge rests on a study of the engineering curricula of American colleges, S. P. E. E. reports, and on discussion with teachers of science and of engineering. Whether all of this is a competent basis for such a conclusive judgment as I shall reach, you will have to decide.

Program for Creative Leaders

In turning to my topic itself, may I emphasize the general subject of the meeting—Educational Preparation for Creative Technical Leadership? My thoughts relate, not to the training of engineering technicians, but to the development of creative leaders, and *therefore to students who possess the natural ability to rise to such leadership.*

I recognize the practical difficulties which may be encountered in accomplishing that object. The means of selecting such students are only partially efficacious, and a program which is most appropriate for the one type of student is utterly inappropriate for the other. But I do not suggest that we are considering an easy problem. It *is* difficult; but it is worth the effort. To do a

good job in the early development of the relatively small group of naturally capable students—to lay a sound, scientific foundation fully appropriate to professional, creative leadership, and to develop mental power—is, in my opinion, the greatest responsibility of our colleges and universities.

So my proposal is to provide a program for such students which shall be designed for the specific purpose of developing engineering thinkers—men with a scientific and scholarly attitude of mind, and with the ability to make the most of experience. Better that we set our course in higher education definitely in this direction, absorbing some of its graduates in the middle levels of professional activity, than to set the course toward the middle, as it now seems to be, and trust to chance and the god of mercy that creative minds will somehow emerge.

Now of course we must have engineering technicians too. An adequate number of technically trained men to "carry on" is just as essential to technological progress as the creative group. Indeed, the two groups are complementary. A rational plan for providing this other and much larger group of engineering technicians would involve two sources. One is the technical institute, which has been the subject of a special report of the S. P. E. E. by Dr. Wickenden. In addition, there would always be a large fraction of college graduates of those courses designed especially for the development of engineering leaders, who were not quite constituted for the intended purpose, but who could nevertheless fill in the gap between the upper and lower levels of engineering activity.

Last Decade

Consider the educational situation of the past decade, and the reasons for it. I refer to the relation which college training in engineering has borne to the requirements in the field, and thus to the performance of the graduates.

The colleges have graduated too many engineering technicians, and too few creative thinkers. For normal business conditions, there may be too few technically trained men, including all kinds, as the National Industrial Conference Board and almost everybody urged before 1929; or, on the contrary, there may be too many, as now appears to those who believe we are entering a new era in which the demand for such trained men will be much less. I do not know. But I am sure of one thing, and that is that there are not enough thinkers. The ratio of thinkers to technicians is too low, and has been so during the decade. Any one who has combed over hundreds of graduates to ferret out the thinkers will appreciate the full significance of this statement. They are hard to find, not

only because such a small portion of them are naturally constituted for any great degree of independent, effective thinking, but also because those few who are, have had so little practice at it under their own steam that their reasoning power is not easily recognizable. Through long disuse it has tended to remain puerile. I am convinced that many young men with minds potentially capable of independent thinking, never have this dormant power in them awakened and developed during their whole lives. The spark smolders under great tonnage of engineering facts, formulæ and figures; it is not uncovered so it can ignite the fire of searching thought, and thus light up their minds. Only in those few students in whom that spark is by nature a dominating force, and who therefore instantly respond to the slight encouragement which it is possible to give them in the present heavy college program—only in such students does it burn its way through to the surface and grow. In the others, such a mass of inert knowledge gradually induces paralysis of thought. Consequently, of the thousands whom the engineering colleges have graduated, too low a percentage have been real thinkers.

It is an interesting phenomenon for our study here—the usual engineering graduate when he faces for the first time in practice a real engineering problem. In learning from others how to do a routine job—for example, the calculation of stresses or densities in design—he is usually very apt; in college he became proficient in making such slide-rule calculations from formulæ. But when a problem confronts him for which there is no formula, what happens? A river to swim, and he can't swim. His muscles may be strong, but they are undisciplined and unpracticed at swimming. He paddles around in shallow water looking for shoals, which are not there, to hold him up in crossing. As the time approaches when he is expected to be on the other side, he is seized with emotions which are dark and despairing. Finally he sees a way; he goes across on somebody's back. It works out all right this time, he thinks; the ride is interesting and also similar to many he experienced at college, so he now knows how to get across next time. Thus he comes to the habit of remaining in shallow water unless he can find a good, broad back to ride on where it is deep.

If my interpretation of the past decade is at all accurate, there is occasion for us to go still deeper into our educational problem than we have gone. I need not emphasize to this assembly the progress which has been made in that period, due largely to efforts of the S. P. E. E. The results are salutary indeed. A trend from specialized to fundamental subjects, toward the segregation of students according to ability, toward a unified program, a keener

interest of teachers inspired by the Summer Schools, etc.,—all of these are worthy, fundamental results. And from them, real improvement is underway *in commensurate respects.* The problem to which I have referred, however, is only slightly touched by them. Subject matter can not solve it; teachers' interest, under existing schedules, can not solve it; and even the segregation of students including an honors group—which is a most promising step—can not solve it merely by a broader and more rapid pace over the same ground in the same direction. The problem is not to be solved by such modifications alone; something more is necessary.

Sailing Direction

It is largely a question of sailing direction—of basic educational objective. As nearly as I can understand the prevailing idea in this country regarding the purpose of all education from kindergarten through college, it is that students should temporarily gorge their memories with facts and figures and rules, about the largest possible number of things, all with the idea that after graduation, much of it will gradually drain off, reducing the plethora and leaving a residue which may prove useful in life. There may be also the idea that the process itself of gorging and elimination is somehow constitutionally beneficial—that it inures the memory structure to heavy burden, like a banquet does the visceral structure. This memory gorging, which in most other college courses is burden enough, is, in engineering courses of American colleges both increased and supplemented by long and exacting tabulations of data, the preparation of numerous routine reports and the like, until the students' time is thus completely consumed. Emphasis is upon memory and techniques of manipulation, instead of upon disciplined, independent thinking. Under such conditions, the development of real thinking power is simply impossible. We have all found it so. Try to encourage the student to pause in his mad rush long enough to do a little thinking, and what is the result? A late laboratory report or problem, or his lesson for the morrow is not memorized. The instructors' time is also consumed on the other half-cycle of this process. So there is no time for the student to practice scientific thinking, or for the instructor to coach him in it. And the clear reason for this condition is that the educational objective has been one sided—or at least lop-sided. It emphasizes learning, and not constructive thinking.

And looking to the future, as long as that is the prevailing objective, we need not look for much improvement in the thinking power of students and graduates. We may make the learning process more effective; we may approach ever nearer to the most

appropriate subject matter for engineering practice; and we may stimulate teachers to a more active interest in their work. But when we have done all these things, we still have not disciplined and exercised and stimulated the student's thinking powers. We can do this only if we set out to do it. We certainly can not expect to do it by setting out to do something else.

My proposal is that we modify our objective. Let us definitely recognize the two essential and complementary aspects of a rational objective. We already recognize the one, but it is, unfortunately, to the practical exclusion of the other. I propose that we add the other on equal footing. Let us affirm that we are going to do two things: first, that we will teach fundamental knowledge and the simpler, essential techniques of manipulation; and, second, that we will coach the student in constructive thinking—in other words, stimulate and discipline his thinking faculties.

Present Procedure

We have considered general objectives; in that light let us now analyze the present educational procedure. We build a good, sound foundation of basic physical and mathematical sciences during the first two years; then move over to the next lot and build the house on the sand of technical engineering minutiae.

As a reason why engineering graduates are unable to *use* their physics, mechanics and mathematics, it has often been suggested that these subjects have not been taught well. I am convinced that this is not the main reason. Instead, it is that the engineering teachers themselves do not use the *fundamental principles* of these sciences in their class work. They use the definitions and formulæ, but that is not using the fundamental principles. Why don't they use them? Because a student can not apply the fundamental principles of any science in the analysis of a problem or situation, without thinking. It is not to be done by memory. And since thinking under one's own power is not fully recognized in the educational objective, it is little done in college programs; and therefore there is no occasion to call these principles out of their mental catacomb. They are consequently forgotten, and that is the reason the graduates can not use them.

The study of engineering, following the study of basic sciences, thus becomes something almost entirely detached. The graduate leaves college with the basic sciences in one side of his head, and engineering in the other. The two have hardly met. Outside of numerous definitions and a few essential concepts, such as symbolism, rates, and those relating to basic physical phenomena—which comprise a necessary basis for the subsequent additional accumula-

tion of engineering learning—there is little continuity between the studies of the first two years and the studies of engineering. Instead of a gradual transition from the learning process in connection with these basic sciences, to the application of them in engineering, there is a substantial discontinuity. And the students, it seems, have consequently come to regard these important, fundamental subjects in much the same category as they classify English and History—merely courses to be passed off.

When they come to engineering, they turn attention to new studies. They learn about machinery and structures and perhaps economics. They learn operating characteristics, how to make tests, how to make calculations by formula which apply to certain type-form, fully specified problems. They learn and learn and learn, facts, formulæ, rules and manual technique. The major part of the busy time in American colleges is thus devoted to engineering minuets, in a form and at a tempo set by the instructor.

Our present procedure is therefore hardly conducive to sound and virile thinking in uncertain situations. It prepares, instead, for routine function. I realize, and once more acknowledge, that this description is somewhat exaggerated; there are, indeed, some who try, against almost impossible odds, to bring scientific thinking into their student programs. But I am not talking about these exceptions; I am discussing the situation as a whole, and the fundamental reason why it is so.

There is another pertinent question which should be raised regarding the present procedure. I have mentioned the trend, accelerated by the S. P. E. E., toward a unified program. It has been unified; but unified around what? Subject matter. Various subjects, practically all relating to engineering are well ordered in a logical and necessary sequence. Few undergraduate programs in other college courses will match the engineering curriculum on that score. But while the program is unified around subject matter, the subject matter itself is not unified in the student's mind. The different branches of it seem to remain separate in his mind, just as they were taught, instead of becoming organically articulated to a central stem. And thus, much of the memorized subject matter becomes inert knowledge which clutters the mind.

Subject matter remains inert until it is utilized in independent thinking. If the multiplication table were learned and then never used in multiplying, it would become as inert as Newton's Laws of Motion usually are in the engineering graduate's mind. Merely to remember that there is a multiplication table which can be consulted if ever, for some unexpected reason, an occasion arises for its use—this would resemble very closely the usual graduate's state of mind with reference to most of the fundamental laws of basic

science. The trouble is not alone that he places fundamental knowledge in such a common-place category; he seems to have been taught from the point of view that since the character of his future work is not predictable, and the possibilities are very wide and numerous, the more subjects he can learn, the higher the probability that he will have included something useful. So the point here is double barreled. Not only are his fundamentals classified with that other less important knowledge, the possible use of which he regards as highly fortuitous; but, having been learned first, they are at the bottom of the heap. Only fragments of it all are *used,* and most of them are from the formulized top. These fragments are used principally in the exercise of manipulative techniques such as, for instance, the application of specialized, half understood formulæ to fully specified cases. Consequently a large portion of his acquired knowledge—a major portion of it, in my opinion—becomes inert and stays inert.

Procedure under a New Policy

Suppose we accept, for the sake of argument, the proposed bilateral educational objective—that the development of thinking power shall be on an equal footing with the development of knowledge and manipulative techniques. What then should be our procedure? It should be simply to guide the students as they learn and think in their field, and thus help them to develop that vital central stem, now missing, around which their newly acquired knowledge can be unified. A. N. Whitehead says:

> "Education is the acquisition of the art of the utilization of knowledge. This is an art very difficult to impart. Whenever a text-book is written of real educational worth, you may be quite certain that some reviewer will say that it will be difficult to teach from it. Of course it will be difficult to teach from it. If it were easy, the book ought to be burned; for it cannot be educational. In education, as elsewhere, the broad primrose path leads to a nasty place. This evil is represented by a book or a set of lectures which will practically enable the student to learn by heart all the questions likely to be asked at the next external examination."

Let us accept his definition of education, and do away with the primrose path. We must still have a path, but its direction must be properly set.

In order to define the direction accurately, I shall reiterate the five Phases of educational process, as I understand it.

1. The first relates to the process of acquiring factual and definitive knowledge. One learns for instance, the factors in the "flexure" formula in mechanics; the definition of "marginal utility"; that the base of napierian logarithms is 2.718. It is the

process of building up one's mental encyclopedia. It is essentially a memory matter.

2. The second has to do with that type of reasoning in which the student is led, step by step, through logical processes either by a teacher, or by a text-book. His part in this particular phase of his journey through the educational forest is not to move precariously along a trail which is only blazed; instead he rides on an educational sight-seeing bus over a modern, concrete highway, of which even the curves and grades are reduced to a minimum. His only responsibility is to take due note of the scenery, and of the announcer's comments as he rides along. For instance, he may be thus escorted through the logical development of the "flexure" formula; of the theory of "marginal utility," or of the vector representation of alternating currents. This process is one of civilization's necessary short-cuts. In order to reach the frontier of new things, to acquire on the way an acquaintance with the methods used there, and yet to have a reasonable portion of one's life still available for professional activity, some such rapid transportation seems absolutely necessary. It is a process of vicarious reasoning. In it one learns to follow logically and to retrace the steps; one's mental muscles are developed somewhat, but they do not become sturdy and of good form by purposeful exercise under their own power; instead, they are massaged.

3. The third phase is the process of acquiring skill in manipulation. For example, one develops skill in algebraic transformations; in numerical calculation from formulæ by the slide rule; in operating a machine; or in carrying out an experiment. It is a discipline in manipulative procedure.

4. The fourth phase relates to that type of reasoning in which the student himself takes the initiative. *He* establishes the trail through the educational forest. The objective may, at first, be defined for him, and perhaps its general direction and a few landmarks may be indicated; but he presses through alone. In clearing away the undergrowth, in fording or swimming the technical streams which cross his path, in retracing his steps for a new start when he encounters an impasse, he not only exercises his mental muscles in worthy activity and stretches them to the elastic limit, but also develops his sense of direction and his power of discerning helpful landmarks. Each successive trail thus established by him increases his pioneering powers; and presently he will be able, if it is in him, to blaze his own trail through new areas to new objectives.

5. The fifth has to do with the establishment of a natural continuity between the development of the individual at college and after college. The branches of a truly educational program will

neither terminate in dead ends here and there during the college course, nor be chopped off at graduation. Instead, they will feed primary educational stems which will both extend and expand beyond graduation as long as the individual is on the ascending slope of his professional career. However, the extension of such stems after graduation is extremely difficult unless the student has already begun to extend them under his own power before graduation. He must develop under guidance both the desire and the power to extend them.

Colleges emphasize largely the first three Phases—*i.e.*, acquiring knowledge, vicarious reasoning, and developing skill in manipulation. What I am proposing is that emphasis be shifted to Phases 4 and 5—*i.e.*, reasoning under one's own power, and the development of primary educational stems.

In most respects we could follow the procedure of the football coach. Excepting certain aspects of his vehement exhortation, his method might well be used as a pattern. In engineering, as in football, there are certain facts and principles which, experience has shown, must be learned and remembered; and also, as in that game, there are procedures which, experience has likewise shown, must be understood and sedulously practiced under discipline. The coach not only tells the player how to tackle; he makes him practice it under discipline until his muscles become hardened to such use and habituated to proper motion and coördination. And as it is with the muscles, so with the thinking mind. We make a start; we tell students how to make calculations when the data are completely given, and then have them practice doing it. That is good as far as it goes. Let us now do the same thing with thinking.

Just what does this mean? How would you train a student to do independent thinking? I should be presumptious, indeed, to urge upon individuals of this assembly any pedagogic formula. My humble purpose is rather to evaluate objectives, and to urge a new direction of emphasis. Every teacher has his own notion regarding detailed method. So all I shall attempt, in this incidental connection, is a sketchy outline of the general plan I have followed for ten years.

The plan is the exercise of reasoning power under a disciplined procedure. That exercise is accomplished in two ways. The first is the application of fundamental principles in the *analysis* of problems; in deducing necessary consequences from known conditions, in those cases where such consequences are actually implied; and in establishing probable consequences when the problem and data are less definite. The discipline is accomplished by a *guidance* in orderly and logical procedure. Let me illustrate. In the first place, problems are carefully selected which are suitable for the

purpose. After the statement of the problem, the following questions arise: what fundamental principle, or principles, govern the case? What simplifying assumptions must be made? What accuracy is required? Specifically what are the conditions which must be satisfied according to those fundamental principles? The answer to the latter question must be a clear, definite statement in English. Then comes the solution. If the problem lends itself to mathematical treatment, that statement in English is merely translated to mathematical language and the conclusions worked out. If not, the conclusions are worked out some other way. In any case, conclusions are reached. Then these must be appraised in light of the assumptions.

The second means is purposeful and thoughtful writing. Composing component thoughts into a logical, organic whole is a powerful mental discipline. The process requires intense thinking, and if it is repeatedly done under effective guidance, mental power will grow. The engineering student presumably has learned the science of writing—the rules of grammar and rhetoric—just as he has learned the other sciences underlying engineering; but, also like the latter, he has not sufficiently *used* it in thoughtful exercise in his later college work. Consequently, in both cases his ability effectively to utilize the sciences he has learned is unduly limited. Again the similarity of the two cases is strikingly illustrated in the unscholarly writing and speech of engineering graduates. Lack of power and clarity of thought is as much in evidence here as it is in their early engineering practice. I am not making an invidious comparison with the writing of graduates of other courses, but with what I am sure engineering graduates could do if they were *effectively coached* and exercised in applying the science of composition which they have learned. My proposal with respect to this science is the same as that with respect to the other sciences —that it be utilized in the development of thinking power.

How can a student compose thoughts if he has none to compose? He can't. One of the vivid memories of my college life is a course known among students as "Daily Themes." How I used to strain my mental ligaments every night to squeeze out a thought for a theme! It is enough, heaven knows, to compose thoughts when one has them; it is simply too much to expect a student, under the pressure of a heavy curriculum, to be a spring of original ideas. However, the literature is full of them, and in the engineering courses themselves the subject matter of reports, exposition and description provide suitable material for such exercise.

But these proposed means of exercising and disciplining mental power require time. If we now have insufficient time to do what we are attempting, how can we crowd in this additional work

which, on equal footing with the rest, would require a significant fraction of the available time? That is precisely the question which must be answered.

If you have a limited time in which to make a preliminary study and report on some engineering matter, you do not spend that entire time collecting data; you reserve part of it for analysis. You adjust your program to accord with the purpose and the available time. You do not collect all the data you want, and you do not analyze the problem as completely as you wish, simply because you can not do so in the limited time; but you do get a start on both, sufficient for the preliminary purpose. Then you plan to extend and complete the work later. We have got to do the same thing here. We might just as well recognize that we can not do all we are doing now, and interpose this additional discipline. We must cut down the now relatively over-emphasized part of the program to make room for the now-under emphasized part. We must balance up. What can not fit in the junior year must be postponed to the senior; and what can not fit there will have to be postponed either to post-graduate or post-college study, and to experience on the job.

However, this process of adjusting the program to accord with both the objective and available time comes second. The primary thought is, what are we trying to do in engineering education?

There is an important distinction which we simply must recognize if we are to keep our thoughts clear on this educational problem. It is the distinction between training engineers, on the one hand, and training students to *become* engineers, on the other. The one is properly done on the job after graduation; the other, in college. It is our job to train them to become engineers. We are not in position to do the other; and it is, moreover, a very uphill task for the graduate to learn how to become an engineer after he is on the job.

We are in position to guide the students to a sound scientific foundation; to discipline them to scientific habits of thought in dealing with engineering material and problems; and to engender the ability and desire to extend both after graduation. They will not be engineers when they graduate, any more than are those who graduate now. But they will be prepared to become engineers very rapidly. With a sound, unified and active scientific knowledge, and with thinking powers disciplined and tuned to effective action, they will be broadly adaptable. They will be prepared to meet uncertainties of whatever character, and hence to become worthy professional men in whatever phase of engineering they may undertake.

My thought, in a word, is that if we are to meet our clear re-

sponsibility to train leaders who will be able to cope with the heavy, complex problems of the future, we must modify our educational objective. It is now one-sided; properly it should be bi-lateral. The acquisition of knowledge and of proficiency in manipulative techniques is only one-half; the other is, as Whitehead says, the art of utilization of knowledge. We must add this vital half to the objective. Instead of paralyzing thought by cluttering the mind with inert knowledge which will never be used, and burying at the bottom of the heap valuable fundamental knowledge, let us, under the pressure of our crowded program, courageously and carefully eliminate debris, and add in its place the vitalizing and unifying force of independent, constructive thought. We are supplying mental food without vitamins; let us plan to provide these also.

CRITICAL ANALYSIS OF THE EXAMINATION SYSTEM OF AMERICAN ENGINEERING SCHOOLS *

By V. BUSH

Dean of Engineering, Massachusetts Institute of Technology

To a group of engineers such as this there is no need to enumerate the benefits of standardization, nor should it be necessary to emphasize the unfortunate results which may follow too early or too rigid an adherence to a standard system. Engineering education in this country is young, but it already conforms closely to a type. One result of the studies and comparisons of curricula continually being made has been to render this conformity more exact in its detail. The present trend toward the licensing of engineers, and the accompanying rating of engineering schools, is very likely to have this same effect.

In speaking before this Society a while ago I contended that it is essential that we should remember that teaching is an art and not a science. Like every other art it has its accompanying technique, but it would be very unfortunate indeed if we should confound the two. No art can be standardized, nor can the technique which underlies an art be restricted to a standard form without a loss of that freedom which makes for progress. Yet our engineering education in this country is moulded in a standardized pattern. Not only are curricula nearly identical, but the method of administering the process in its detail is generally the same. I believe that the primary reason for this lies in the system of examinations to which we habitually adhere.

It is my thesis that our present system of examinations, as generally in use at American engineering schools, is illogical, antiquated, and damaging to our product, and that there is something we can do about it.

Except for a few notable examples, our instruction is given by subjecting the student to a large number of individual independent subjects, which must be passed in a rigid sequence. The passing of a specified number of these completes the process and the degree is conferred. Each subject is substantially under the control of a single teacher who chooses the content, conducts the classes, makes up the final examination, grades it, and reports the

* Presented at meeting of New England Section, S. P. E. E., University of Maine, October 8, 1932.

records. There is some modification of content in its generality by conference between teachers in interdependent subjects, or by control by a head or committee on curriculum, but the detailed content and the mode of instruction remain with the teacher. The conduct of examinations is in the hands of the teacher of the subject. A significant fraction of the time, in some courses the majority of the time, is spent in examining the student.

It is easy enough to see how we arrived at this system. The engineering schools inherited it from the colleges of liberal arts. They in turn took a great deal of it from the little red schoolhouse. The schoolhouse came by it honestly, for there was usually only one teacher to a school and she did everything that was done.

The simplest way to start a college is to hire a teacher for each subject thought to be essential to a satisfactory curriculum and then leave all matters pertaining to that subject entirely in his hands. In the rapid creation of colleges in this country this is unfortunately the procedure which has sometimes been followed, with little study of the pedagogical needs. Then, too, where certain subjects are highly specialized, there is often only one member of a faculty who professes knowledge of a given subject in the program. This certainly should not be so in connection with undergraduate engineering instruction, but it often is.

So we have developed a system of many independently taught subjects, and the student is required to run gauntlets of high frequency and intensity, presided over by satraps, and he does little else during his undergraduate academic experience.

It is a system easy to administer, it keeps members of the faculty isolated and hence relatively at peace with one another, and it yields a set of figures which are convenient as indices in a mass educational scheme.

But its unfortunate results are many, and it is reasonable that a group of the sort present at this meeting should be able to examine them frankly.

1. The student "takes courses" instead of studying subjects. He studies a text, and often the entire sum and substance of his acquaintanceship with a subject is the part of that single text which is not omitted by orders of the instructor.

His whole emphasis is placed on passing the course rather than on obtaining a comprehensive and abiding grasp of the subject. When the course is passed he forgets it as far as possible. Our system of education degenerates into a sequence of forgetting points.

2. The examinations usually overemphasize the immediate and fragmentary.

There is often an undue weight on a formula, or a figure, which

will assist in making grades. Sometimes the weight is placed on an item known to be the pet hobby of the instructor.

There is little opportunity in an examination of ten or a dozen questions for a student to illustrate his ability to carry through a complete careful process of reasoning. Faced for several years with the necessity for arriving at an answer to nearly every question propounded within six seconds or six minutes, he jumps at conclusions, rushes to the use of a stereotyped formula, loses the capacity to reason around a situation, and in general develops those attributes which apply to the clerk rather than to the professional practitioner.

3. The student is hounded. In four years the student has to take some forty or fifty independently taught subjects, in which he is examined formally a total of perhaps one hundred times, and informally several hundred more. His hours are crowded and closely scheduled; he has little time for reading or reflection, and he does little such. All but the exceptional students become automatons.

Moreover, there is a contest between instructors for his time which intensifies this situation. It is perfectly natural for most teachers to consider their own subjects relatively more important than is indicated by the apportionment of catalog time. It is highly unnatural, however, for a student to be responsible simultaneously to eight or ten independent masters, many of whom have that idea, and of whom some are forcing him to devote excess time to their specialties. It is all very well to say that we can rely upon the inherent fairness of the teaching profession; certainly we can. But we can also rely on some teachers being human. Their well meant and often unrealized tyranny is imposed by means of the uncontrolled examination.

4. Our examinations are poor. By and large, with of course notable exceptions, I am convinced that the examinations we give are faulty in many respects.

In reading over examinations of the type we have under consideration, as I have met them from many institutions, I am struck by the fact that they are often ambiguous, that questions are asked which can be answered only by one familiar with the explicit phraseology of the examiner, that directions are given to make a statement in a few minutes which would require an hour for its proper composition, that student memories are being taxed with data which any reasonable practicing engineer would keep in notes or a handbook, and that hobbies are being ridden hard.

From my student days I can well remember the collections of previous examinations, the privilege of consulting which was sometimes obtained in devious ways, and which were usually in the

hands of fraternities or other perpetuating student bodies. A review of previous papers set by some professors would at times disclose in detail the questions of a forthcoming examination, for the simple reason that it was by this same process that it was compounded.

5. The interrelation between subjects is often lost. The dependence of professional subjects upon the basic work which has preceded is often little more than a pious hope. Since engineering is applied science the professional subjects should certainly link together and exemplify the applications of the mathematics, physics and chemistry which have gone before, with proper attention to economic practicability. Yet if we review the material presented in the usual basic courses a large fraction will be found which is never heard of again by the student during his undergraduate career. This fraction may well be worth studying for its own sake, but that is not the point. With the present scientific trend of engineering practice there is an opportunity to utilize to advantage all of the basic science that can possibly be crowded into the basic preparation, and this opportunity is being lost.

Nor is the interdependence of various professional subjects thoroughly emphasized. It is possible, for example, for a student to study in one department the vibrations of machines, and in another the performance of alternating-current networks, without ever realizing that from a mathematical standpoint they are one and the same thing.

There is a more far-reaching influence though. The student finds nearly every instructor he meets to be apparently a narrow specialist with an interest only in the minutiæ of a very limited field. Seldom does he work with a teacher who tackles in his presence a comprehensive engineering problem in its entirety, drawing his tools from various sources. However broad the interests and experience of a teacher may be, catalogue descriptions leave him little opportunity to treat broad engineering problems as a part of a specific engineering subject. The thesis, or the professional elective, offer a slight relief to this situation. In general, however, instructors stick very close to their subjects, and do not endeavor to show how the interlinking of knowledge is a prime function of a professional engineer. The student, therefore, then emerges from the process with the detailed knowledge of the technician, but with little of the grasp of the professional man. Traced to its source the real reason for this situation appears to be the existence of the set of independently taught subjects with their own examinations, and the lack of any examination of a student's grasp of the interrelations of subjects with a consequent lack of instruction in that interrelationship.

6. The student is turned out into the world while still a schoolboy in his attitude toward his professional work.

We cannot treat a student as a schoolboy, and then have him suddenly become a professional man on graduation. We should not expect this to happen, and in general it does not happen. In professional study the student should be to a considerable extent the arbiter of his own affairs. If, when at that state of maturity, he is incapable of serious work except when forced by an implacable system to meet certain rigid daily appointments and detailed tasks, he will usually be capable of becoming an employee on engineering work but not a professional engineer in the highest sense. When suddenly released from control he will quit further study on his own initiative. In all his mental processes for many years thereafter he will be inherently a cog in a system specialized for certain specific subordinate activities, and not an independent creative master of the application of the fruits of science for the benefit of mankind. He will not take a part in public affairs, for he will not take an independent self-reliant part in anything. If he has an engineering project to present to the layman he will do so lamely, for the world is not impressed by the choppy fragmentary exposition that is acquired by answering an interminable series of short questions. I generalize, of course. There are exceptions. Applied to those who, I have stated, are incapable of ordering their own affairs during undergraduate professional study, the indictment holds.

We examine repeatedly whether a student can respond accurately in a closely delimited situation where we supply a specific stimulus. We do not examine, except in the thesis and then none too rigorously, whether he has initiative, resourcefulness, breadth of grasp, powers of comprehensive analysis, balanced judgment. The student quite naturally believes that if he meets our tests he is prepared for a professional career, and we delude him.

7. The outstanding teacher is difficult to discover, and prôper promotion is one of the most difficult tasks which confront the educational administrator.

The engineering teacher has four major professional activities in which he may take part: first, and of course foremost, teaching; second, research, writing, and the affairs of national professional societies; third, participation in the committee work and other internal affairs of his institution; and fourth, professional practice, either during vacations or during term time. Now it certainly is true that the best interests of the student body of any educational institution, and hence in the long run of the institution itself, require that men of outstanding ability in the first of these, teaching, be diligently recruited, properly coached in their youth, and vigor-

ously encouraged by due recognition as they attain to full stature. Yet how often we feel that the surest road to promotion in the teaching profession lies in attainment in the other three fields! Excellent teaching unattended by accomplishment in the other fields may be carried on year after year, without its presence being appreciated by anyone but the inarticulate students who take so long to become influential alumni. Fortunately for our progress, ability in teaching is seldom thus unaccompanied; and in fact it is almost impossible for a man to be an inspiring teacher who does not also do some of these other things well. It is decidedly unfortunate, however, that the judgment of the teacher should be based so largely on activities secondary to his instructional function.

There are several reasons which militate against the proper recognition of outstanding teaching ability, however zealous in that regard the administration may be. It is a highly intangible quality that is defined with difficulty. The rate of overturn of the product of a faculty is so slow that it sometimes takes a generation to distinguish on the basis of ultimate results between real teaching and what appears to be real. But there is another and very definite obstacle in the way, for except during apprentice days, the results of a man's teaching are examined in the school only by himself.

Now, why do we continue to adhere to this system with all of its easily recognized defects?

It is difficult to construct out of whole cloth a better system; there is the very natural tendency to multiply a type of known operativeness; and, from the standpoint of the teacher, there are some aspects of the present system which are quite comforting. It is, of course, much more soothing to examine one's own product than to be subject to scrutiny of one sort or another. Students are tractable when they are under complete control by a grade. A subject that remains static in content or treatment requires little effort to teach, and the present scheme does not force modifications.

Yet it is not hard to recognize that the present is a time of change in nearly every field of endeavor, and that many forms of organization and activity long static are becoming decidedly dynamic. As far as the teaching profession is concerned, there are some phases of the present situation which are salutary. The man of business does not now look upon the teacher as a singular creature who for some strange reason is content with a quiet life and an inadequate income. With its comparative security, its well recognized intellectual advantages, and its much increased relative return, engineering teaching is proving to be an attractive profession. There should be no difficulty in securing recruits of high calibre for some time to come, for even if prosperity returns the lesson will not be quickly forgotten. Hence we are experiencing a singularly apt

time in which to put our house in order wherever we find on judicial introspection that reform is necessary. We can well consider our antiquated system of examinations a case in point.

If we conclude, then, that our educational scheme has serious faults and that these center largely about the retention of a multiplicity of subjects, with their detailed examinations, and an absence of examinations which force attention to broader phases of education, the obvious procedure is to change and to introduce a more effective scheme. There are several questions which arise immediately when this is proposed, first, the inquiry whether a change is possible at all in view of the conservative opinions widely encountered among engineering teachers, second, what the possible nature and the advantages of a substitute system might be, and finally the question of what a change of the sort would cost.

One alternative system is that of the comprehensive examination, which has already been studied extensively in this country by progressive educators, particularly in the colleges of liberal arts. It is time that we honestly admitted that the engineering schools have lagged far behind the arts colleges in the development of the broader scheme at which the comprehensive examination aims. We will soon have a report on this matter, for the Association of American Colleges has conducted an investigation of comprehensive examinations in some fifty colleges, and is due to report this fall. There is hence no need to summarize the situation here, and indeed an analysis of the workings of various schemes would require far more time than we have at our disposal. Of course the scheme itself is much older than America, and the adaptation to American conditions, rather than the creation of a new procedure, is the problem to be studied. In this we can well lean on the careful experimentation which has gone on about us, and the advice of those who are already pioneering in the engineering field. Harvard * has had general examinations for twenty years. These are comprehensive in the major field of study, and have been adopted by nearly all undergraduate departments of the University, but not in certain sciences or in engineering. The tutorial system which is an essential part of the scheme is worthy of any educator's serious study.

Another striking example is found in the Medical School of Yale University. Here there are subjects, but not courses in the ordinary sense. There is no required attendance, nor are there any examinations in specific subjects. A student has two comprehensive examinations; one at the end of his pre-clinical work, given by the clinical group to determine whether he is ready for advanced

* "General Examinations and Tutors in Harvard College," March 28, 1932. Published by the University.

medical study; and the other at the end of his clinical work to determine whether he is ready for the degree. No student is required to take either examination until he himself wishes, and he may cut short his period of residence to some extent by a successful early appearance. The examinations contain written, oral and practical work. The school admits about fifty each year from about five hundred applicants. I refer you to the very interesting papers of Dean Winternitz for further particulars.

The experience of Swarthmore is highly illuminating and has been summarized for us by Professor Brooks.* We have also the pioneer work of Professor Jackson before us.† These are particularly pertinent, as the engineering school problem is in some ways unique.

A review of all this experience, as far as it has been reported, indicates that, when accompanied by proper provision for guiding students, and when selection is wise, the scheme of comprehensive examinations has been notably successful. Admitting that its introduction into engineering education will involve a great deal of work, some missteps and controversy, I am convinced that when wisely administered it is well worth all that it involves. It can give us relief from many of the glaring defects of our present scheme, and it can produce other new results not now generally produced in engineering education.

There is some strenuous criticism that we are training too many engineers. The Junior College movement is one result. The fact is, as most teachers will admit, that many of those we have trained are not engineers at all in the proper professional sense, but technicians, valuable to society although improperly educated for their destined future. We have been training technicians and professional engineers together in a process which is not well adapted for either. As we change, the growth of the honors system for the professional group, or something closely resembling it, is inevitable.

Certainly, with this situation before us, it is incumbent upon

*"Reading for Honors at Swarthmore." Robert C. Brooks. Oxford University Press, 1927. See also "A Study of the Liberal Colleges." Leon B. Richardson. A report to the President of Dartmouth College.

†"Educational Processes as Employed in the Department of Electrical Engineering at the Massachusetts Institute of Technology." J. W. Barker and R. H. Frazier, JOURNAL OF ENGINEERING EDUCATION, March, 1929, p. 619. "Needed: New Life in the Colleges." D. C. Jackson, *School and Society*, September 28, 1929, p. 415. "Honors Study in Engineering." R. H. Frazier, *Technology Review*, January, 1930, p. 147. "The Honors Group Plan." R. H. Frazier, *The Tech Engineering News*, April, 1930, p. 85. "A New Era in Engineering Education." R. H. Frazier and H. L. Hazen, *The Bent of Tau Beta Pi*, January, 1931, p. 15. "Educating for Responsibility." R. H. Frazier, *Technology Review* (to appear in November, 1932).

engineering teachers to act constructively. The evils of the present system cannot be removed by minor changes, for they are inherent. A reasonable conservatism in teaching methods is laudable, but we should not allow it to impede our progress, for it appears that we are dangerously near to being left behind the procession.

The term *comprehensive examination* may have various meanings. Such an examination may be comprehensive in scope, or it may test the comprehension of the student as opposed to his memory of facts. I will use it to mean an examination which tests the grasp of a large associated group of subjects, emphasizing the interrelations, searching and not superficial, with its primary emphasis on the analytical powers of the student, yet with a due attention to the development of habits of accuracy and observation.

There are several places in our procedure where such examinations may be advantageously introduced. First, there would be real advantages, and also serious practical difficulties, in imposing a comprehensive examination as a test of fitness to enter the engineering school. Second, at the end of the period of basic studies such an examination may be used to determine fitness to enter professional study. Finally, and most important, the comprehensive examination may become the single hurdle to be surmounted before obtaining the degree. It is on this latter use that attention should be focussed, as it is thus that such examinations will usually first be adopted.

The introduction of a final comprehensive examination should ordinarily be accompanied by some form of counselling or tutorial system, for careful guidance of students will be needed. Relief from detailed examination in specific subjects, and even from any required attendance at classes, is connoted.

It will be advisable that a change in systems be gradual, not only because students in general will need to develop a new attitude toward their work if they are to profit from increased freedom, but also because the staff will require time for adaptation as well. At first, in most institutions which are in a position to alter their methods at all, the scheme will certainly be applied to selected groups of students, and we will then have so-called honors groups, but ultimately I feel sure the system should be extended to all students in the upper classes of professional engineering study, and selection processes should be developed which will bar at the outset those who cannot successfully undertake the responsibility of ordering their own lives. The time will come, and that sooner than many anticipate, when it will have to be frankly realized that the school which insists on spoon feeding as an educational process is not training professional men.

There is a natural division of our work into basic, professional and graduate studies. For students seeking advanced degrees we already place emphasis on student freedom and comprehensive examination in most cases in which graduate work is in fact really advanced in its nature. The doctorate in engineering, as well as in science, is largely centered about a major examination and a thesis. Some study for the master's degree is similarly oriented, although a great deal of such study comprises simply a year's extension of the undergraduate treadmill. If our period of undergraduate professional study is professional in fact, it must soon come to partake of this same nature.

In the period of basic study we may well have a period of transition. Here, and in the preparatory study, those detailed working tools which are necessary equipment should be acquired, the habits of industry and accuracy should be engrained, mental discipline should be the watchword. It is too much to hope that the preparatory school will completely accomplish these things. Certainly, however, the period of basic study in college should be able to complete the task and to do something else besides. That something else should be to prepare the student's mind for the professional life by providing an introduction to those independent processes of thought which are the prime attribute of the professional man. This means a gradual release from detailed control, under guidance. It means also the partial substitution of a single comprehensive barrier to be surmounted in place of a multitude of low hurdles. An examination to test general fitness for professional study appears to be decidedly in order.

The development of a proper system of comprehensive examinations, together with an adequate provision for student guidance, will take time; and it is to be hoped that the final product will differ markedly in individual schools. There are a few points on which I have already become convinced as a result of experience with honors group work, and these may be briefly touched upon, but a divergence of opinion on the details of the plan is very welcome, for it may lead to a much needed individuality among schools instead of the present lockstep on curricula and methods.

First, I believe the examination must ultimately and for best results be entirely controlled and directed by the individual school, and given by its own faculty. A general examination of national scope, dictated by government or a national society, would have one disadvantage that would override in my opinion its obvious advantages. This would be the tendency toward bureaucratic domination, the dictation of a fixed type, the submergence of that individuality of separate schools which is inherent in the American

concept. The professional man should be a creature of too highly developed individuality to be subject to close standardization. We have altogether too close a parallel between the existing activities of engineering schools.

The practice of some states which now require an examination for professional registration as an engineer, comparable to that in medicine or law, may be extended to all states, or even nationally. Such examinations have a proper purpose, to bar from professional practice those who have not invested with success a specified minimum of time and effort in preparation for a professional life. But the comprehensive examination I have in mind is for a different purpose. The Medical School of high standing gives its own examinations for the degree, and expects that its graduates will pass the governmental examinations with comparative ease. The governmental examination sets a minimum standard, and that is its proper scope, while the comprehensive examination of the individual school should go beyond this and set the standard of the institution, the basis on which its reputation depends. Moreover, it should provide the emphasis to give each institution its mark of character and individuality, without which any professional training would cease to develop in the broadest sense.

While the advice of practicing engineers is exceedingly helpful and they should, of course, be consulted, the examiners should be faculty members. After all, the giving of a proper examination is an art, which is acquired only after long experience and thoughtful study, and it cannot ordinarily be learned by the practicing engineer as a side issue in a moment. Unquestionably, the practicing engineer of prominence is ready and willing to help, and in fact the generous attitude of practicing engineers toward the activities of our schools is phenomenal. Their contribution, however, is best made by suggestion and criticism, and the responsibility for the examination with its detailed formulation and application should rest squarely on the shoulders of the professional teachers, upon whose devotion and skill the ultimate reputations of their institutions depend.

The comprehensive examination will, and should, require much time and effort on the part of the faculty. It will require less time than the present fragmentary system of examining students continually, but it will be a task of considerable magnitude when applied to large numbers of individuals.

It should be searching and thorough, a real barrier and ordeal, so that it will not be entered upon lightly, nor will its outcome be generally predictable. Such an examination will automatically bar those of a timid nature who are unwilling to stand on their own

feet and struggle with severe obstacles. It is well that such should be discouraged from attempting to enter the profession of engineering, which is not a sinecure.

It should be comprehensive. As such it will need to be both theoretical and practical, or better, basic and applied. It will probably be written and oral, and it may well include as a component part the individual creative project of the thesis.

Its nature should be public and well advertised, that students may be continuously apprised of the professional attainment expected of them, but its sessions should be private in order that they may be searching and intimate. Certainly its oral portions, and perhaps even its written parts, should be adapted to each individual candidate. The examining group should usually be small, and the sessions should approach conferences, but there should be enough sessions and enough examining groups to cover the ground.

These are my own opinions, and the ultimate form of the comprehensive examination must evolve as a result of a consensus of opinion. I hold a brief principally for its rigor, comprehensiveness and individuality among institutions.

There is no need to dwell at length upon the advantages of the comprehensive examination system, for most of them are obvious from a study of the defects of the system we now have. There are some that are not immediately apparent.

One result of value is a new and finer relationship between student and teacher. It is not a simple matter to develop genuine friendship and a partnership in scholarly endeavor when the teacher is taskmaster, judge, and executioner. It is a highly encouraging light on our collective American character that such development occurs at all under present conditions. But when the artificial constraint is removed, when it is assumed at the outset that a student is striving whole-heartedly to prepare himself for useful service in the world, when the attention of the teacher can be directed to aiding the student to educate himself, there is a far larger opportunity for the exercise of that mysterious quality, which we all recognize and which none of us can define, that makes for power and lasting influence in an inspiring teacher. We may have systems galore, but the essential core of education is the individual teacher in his intimate contact with the mind of his student. If the changed system did no more than to provide greater opportunity for the teacher of inborn excellence to practice his art, it would be worthy of support.

I do not advocate a sudden and suicidal change of front. We have erred too long, and the atmosphere created by our present system of minute control over every academic act of the student renders sudden release dangerous. We can never make the change

completely without an improvement in the selection process and hence we must experiment at first with selected honors groups, and look well to the modifications of our present archaic scheme of admission. We may be sure, however, that when a gradual and properly constituted change discloses those students who are constitutionally unadapted to use freedom to advantage, it has also uncovered those who are not adapted for a professional life. We should not rush headlong into a system of complete student freedom, even under constant advice or tutelage, with comprehensive checks only after relatively long periods of study. Before this can be safely embarked upon, the student body must be weaned from its long inculcated habit of considering academic duty done when it has taken a daily prescription of study. It is hence pertinent to discuss palliatives.

It is no more than fair, for one thing, that all of our important written examination papers should be reviewed by someone unconnected with the teaching of the specific subject for the purpose of uncovering ambiguities and other faults before the papers are administered. It is also good practice to try them out for length of time required, by a process of evaluation which consists in timing an assistant, also unconnected with the course, while he takes the examination, and adding a liberal percentage. This, parenthetically, is not at all bad for the assistant, who after all, is an apprentice teacher.

Joint composition of examinations by the group engaged in teaching a subject is excellent, as is joint grading, and these processes are frequently practiced. But I do not know of any instances at present where subject examinations are entirely set and graded by members of the faculty who are not associated with the teaching of the subject. This is a step that has excellent possibilities.

Personally, I see no reason why the final examination in a subject should not be open to any student who wishes to take it, even if he has not formally taken the subject in course. If the examination is an accurate test there would seem to be no valid objection to this procedure; and if the examination is based on the subject and not on the specific details of one formulation of it, I believe there are many youngsters in college who could and would study on the side and pass examinations for advanced credit greatly to the relief of their schedules. Why, incidentally, are practically all of our undergraduate examinations written rather than oral, although we complain that our graduates cannot present their cases strongly in an interview? The possibilities of oral examinations in undergraduate work are interesting.

There are undoubtedly other ways in which our present scheme of examination may be improved. Since we certainly have it with

us for a time, and since it may always be adaptable to technical as contrasted with professional engineering education, it should be improved if that is possible. Ultimately, however, and where professional engineering education is concerned, I feel it is wrong. I would not improve it. I would abolish it, as rapidly and generally as is consistent with the careful development of a substitute.

Finally, we have to consider what a system of comprehensive examinations would cost. In one sense it would cost all of the money an institution could obtain for educational purposes, for that is what every system costs. A more proper measure is the cost per student, and we may consider that the question therefore may be resolved into the problem of the number of students that could be admitted and carried in view of the endowment or appropriations available. The experience of Harvard seems to be that the cost per student under the system of general examinations and tutors is not far different from the figure that would have been arrived at if the old system had been continued up to the present. This is probably due to the fact that money, which under the old system would have been used for an expansion in the variety of subjects offered, has become available to cover the cost of tutors. There is no doubt whatever that the superposition of a comprehensive examination system upon the existing system, leaving the latter intact, would be an expensive process. It is not at all demonstrated, however, that the cost per student would be any greater under the new system after a complete change had been made, assuming that a sufficient amount were expended in each case to do the work thoroughly as far as the system allowed. Of course there is no limit to the amount that can be expended per student under either system, in one case by providing a multiplicity of courses with small classes, and in the other more time of the staff devoted to individual student guidance. The question to be answered is whether one system gives better results for each dollar expended per student than the other. It appears to me clear that, when the amount of money available is adequate to provide proper professional training at all, it can produce the best results if devoted to that system which has the fewest faults and the greatest advantages to the student when considered strictly as a system of professional training.

In conclusion, I am convinced that a just estimate of our pedagogical processes in engineering education today will conclude that in our undergraduate work we depart sadly from the true nature of professional education. The essential reason for this is that we have held to an antiquated system of a multitude of loosely connected subjects with their own fragmentary examinations. It is time that we progressed. The road is open in at least one direc-

tion by the gradual and guarded introduction of a system which will extend to the student self-determination in his academic activities under wise and ever-present counsel, create an atmosphere of transition from the attitude of the schoolboy to that of the professional man, which will eliminate those who cannot stand the freedom of professional life, and nurture the individuality, initiative and resourcefulness of those who can. The central feature of this development is the comprehensive examination which must yet evolve into full effectiveness.

ANALYSIS OF THE PERFORMANCE OF COLLEGE GRADUATES IN STRUCTURAL ENGINEERING *

By ALBERT REICHMANN

Engineering, in a broad sense, is the science of utilizing the materials and forces of nature to serve the interests of mankind. It is the knowledge of the composition and behavior of materials, the application of the different forms of energy, the forces of nature, and the principles of science.

Engineering development is the result of training and research. Technical institutions of learning, technical societies and publications, as well as laboratories, contribute to its progress.

There are many branches of engineering: Structural, mechanical, electrical, architectural, hydraulic, sanitary, mining, chemical, metallurgical, gas, military, naval, fire protection, and ceramic.

As considered in this analysis, structural engineering is the application of engineering principles to the design and construction of projects, irrespective of the materials used, such as bridges, buildings, tanks, towers, tunnels, locks, dams, piers, docks, flumes, runways, etc. The duties of the structural engineer comprise the selection of sites, making of designs and estimates, superintendence, investigations, appraisals, inspections, reports, and recommendations in connection with these various structures.

The choice of a profession is a problem of vast importance to a boy before entering college. He should give careful consideration to his selection, otherwise he may be disappointed in later life. The boy should be guided by the counsel of his parents, the judgment of older experienced friends, as well as his own inclination and aptitude.

One boy reached his decision after employment in eight different occupations during the vacation periods of both high school and university. As a result of his experience, he chose engineering, and after graduation decided that his qualifications fitted him best for sales engineering. His instructors and friends in the profession concurred in his judgment. The varied experience he received during vacations not only helped him in the selection of his profession, but also gave him a broader general knowledge which later was of material assistance to him in his work. Since gradua-

* Presented at the 40th annual meeting, S. P. E. E., Corvallis, Oregon, June 29–July 1, 1932.

tion he has been employed continuously by the same company with considerable success as a sales engineer.

Unfortunately, many college graduates are unable to choose the employment for which they are best qualified, or the employment which would offer the greatest opportunities for advancement. As a consequence, they become dissatisfied with their work and make frequent changes to improve their conditions.

The engineer who frequently changes his position discovers after he finally decides to cast his lot with a particular organization that he has lost certain priority rights and that younger engineers with longer service are given preference in many cases, as their seniority outweighs the broader experience of the former.

Many graduates place too much consideration at the start on initial compensation, working hours, and surroundings, and not sufficient consideration to the possible opportunities for advancement and ultimate success, with the result that they eventually find themselves employed in subordinate positions with few responsibilities and small salary.

A graduate should decide at an early date whether or not to practice in general engineering, and if he so decides, he should set out to secure varied experience. If, on the other hand, he intends to specialize in a particular field, he should not spend too much time in work not related to his chosen profession. For instance, a graduate who decides to specialize in steel design should have shop and field experience and a thorough knowledge of concrete and timber construction. Vacation periods, as well as the first year or two after graduation if necessary, can be used to advantage in securing practical experience.

Civil Engineering Graduates in Structural Engineering

An investigation was made to determine the number of civil engineering graduates employed in structural engineering and the degree of responsibility of their present positions. It was difficult to obtain information along these lines as the records of the universities which coöperated in this investigation are either incomplete or not comparable. Only nine colleges of twenty-six solicited were able to supply the data desired.

It was found impossible to ascertain reliable facts relative to the number of civil engineering graduates entering structural work immediately after graduation for comparison with the number of those remaining in this field at the present time in order to arrive at a percentage of engineers leaving structural engineering for other pursuits, and therefore, such percentage is omitted in the tabulation.

The classification for the degree of responsibility is the same

as that in use at one of the leading universities. It is arranged in five divisions, as follows:

A. Administrative: president, vice president, general manager, partner, dean, assistant dean.

B. Supervisory: chief engineer, engineer in charge, director, head of department, city manager, consulting engineer, manager.

C. In charge: construction engineer, maintenance engineer, design engineer, field engineer, county engineer, professor, associate professor, location engineer, operating engineer, research engineer, testing engineer, chief draftsman, promotion engineer, materials engineer, sales engineer, superintendent.

D. Routine work: assistant professor, foreman, instrument man, instructor, inspector, draftsman, detailer.

E. Sub-engineering work: rodman, chainman, tracer.

Graduates for the years 1900 to 1932 inclusive were considered in the investigation with separate groupings from 1900 to 1907 and in five-year periods from 1907 to 1932. The number of graduates, with the degree of responsibility of their positions, is shown in each of these groups.

The total number of civil engineering graduates investigated is 6408.

The number in the structural field at the present time (1932) is 2265, which is 35 per cent of the total number graduating in civil engineering.

RESPONSIBILITY OF LAST KNOWN POSITION:

TOTAL NUMBER 2265—100 PER CENT

Graduates, 1900 to 1907 inclusive	382	17 per cent
A. Administrative	87	4 per cent
B. Supervisory	130	6 per cent
C. In Charge	140	6 per cent
D. Routine Work	23	1 per cent
E. Sub-Engineering Work	2	0 per cent
Graduates, 1908 to 1912 inclusive	416	18 per cent
A. Administrative	75	3 per cent
B. Supervisory	109	5 per cent
C. In Charge	205	9 per cent
D. Routine Work	25	1 per cent
E. Sub-Engineering Work	2	0 per cent
Graduates, 1913 to 1917 inclusive	331	15 per cent
A. Administrative	41	2 per cent
B. Supervisory	82	4 per cent
C. In Charge	173	8 per cent
D. Routine Work	34	1 per cent
E. Sub-Engineering Work	1	0 per cent

RESPONSIBILITY OF LAST KNOWN POSITION—*Continued*

Graduates, 1918 to 1922 inclusive	363—16 per cent
A. Administrative	36— 1 per cent
B. Supervisory	45— 2 per cent
C. In Charge	174— 8 per cent
D. Routine Work	107— 5 per cent
E. Sub-Engineering Work	1— 0 per cent
Graduates, 1923 to 1927 inclusive	478—21 per cent
A. Administrative	16— 1 per cent
B. Supervisory	26— 1 per cent
C. In Charge	183— 8 per cent
D. Routine Work	240—10 per cent
E. Sub-Engineering Work	13— 1 per cent
Graduates, 1928 to 1932 inclusive	295—13 per cent
A. Administrative	1— 0 per cent
B. Supervisory	5— 0 per cent
C. In Charge	31— 1 per cent
D. Routine Work	245—11 per cent
E. Sub-Engineering Work	13— 1 per cent

Members of an Engineering Society

An investigation was made of the membership of a large engineering society for the purpose of classifying the members engaged in the structural field. The total membership of this society is more than 2800, of which 1012 are employed in structural work. These are classified into 43 divisions according to the position held or the kind of organization, whether colleges, consulting engineers, contractors, etc.

The tabulation is based upon the positions designated by the members. Engineers are not always explicit in the use of terms to designate their positions, and consequently, the classification is inaccurate where indefinite terms were used. For instance, 35 men are classified as "structural engineers" who could have been identified under several other headings.

1. Architectural Engineers	12
2. Army Engineers	4
3. Building Commissioners	2
4. Colleges—Executives, Heads of Departments	7
5. Colleges—Professors, Instructors	13
6. Consulting Engineers—Members of Firms	139
7. Consulting Engineers—Engineers	42
8. Consulting Engineers—Designers	56
9. Consulting Engineers—Superintendents of Construction	12
10. Contractors—Members of Firms	64
11. Contractors—Engineers	36
12. Contractors—Estimators	5
13. Contractors—Construction	17
14. Editors—Engineering Publications	12
15. Erecting Engineers	2
16. Engineers on Research Work	17

17. Fabricators—Members of Firms	22
18. Fabricators—Engineers	50
19. Fabricators—Contracting Engineers	43
20. Fabricators—Designers	27
21. Fabricators—Estimators	10
22. Fabricators—Detailers	28
23. Fabricators—In Charge—Shop Departments	10
24. Fabricators—Construction	18
25. Inspectors and Engineers of Tests	26
26. Municipal, State and Government Engineers—Executives	5
27. Municipal, State and Government Engineers—Engineers	46
28. Municipal, State and Government Engineers—Designers	42
29. Municipal, State and Government Engineers—Construction	15
30. Navy Engineers	1
31. Railroad Engineers—Presidents, Vice-Presidents	7
32. Railroad Engineers—Engineers	60
33. Railroad Engineers—Designers	38
34. Railroad Engineers—Field	30
35. Retired	4
36. Specification Writers	1
37. Structural Engineers	35
38. Surveyors	7
39. Utilities—Presidents, Vice-Presidents, etc.	1
40. Utilities—Engineers	14
41. Utilities—Designers	7
42. Utilities—Construction	14
43. Valuation Engineers	11

The men were classified into five groups according to the degree of responsibility of their positions. Comparatively few engineers in subordinate places are members of engineering societies, which will account for the smaller percentage under Class *D* than one would expect.

A. Administrative	39— 3 per cent
B. Supervisory	212—21 per cent
C. In Charge	371—37 per cent
D. Routine	383—38 per cent
E. Sub-Engineering Work	7— 1 per cent

Service Records of Engineers

For the purpose of studying the different positions held by engineers before reaching positions of responsibility, quite a number of records of engineers were investigated and several have been selected as being typical of many successful engineers, which are as follows:

(*a*) Graduate, 1892: Superintendent of construction, 11 years, Government; structural engineer, 11 years, consulting engineer; consulting engineer, 18 years, self; three positions in 40 years.

(*b*) Graduate, 1897: Draftsman, 1 year, fabricator; bridge draftsman, 2 years; designer, 2 years, railroad; designer, 1 year,

consulting engineer; assistant engineer, 3 years; bridge inspector, 3 years; bridge engineer, 23 years, railroad; seven positions in 35 years.

(*c*) Graduate, 1900: Instructor, 1 year, university; bridge designer, 6 years, consulting engineer; principal assistant engineer, 7 years, consulting engineer; consulting engineer, 18 years, self; four positions in 32 years.

(*d*) Graduate, 1904: Instrument man, 3 years; field engineer, 3 years, railroad; office engineer; principal assistant engineer; assistant chief engineer; chief engineer, 22 years, railroad; six positions in 28 years.

(*e*) Graduate, 1901: Teacher, 3 years, municipality; draftsman, 2 years, fabricator; shop inspector, 2 years, fabricator; designer, 1 year, consulting engineer; structural draftsman, 1 year, fabricator; designer, 3 years; chief engineer, 8 years; engineer of bridges, 15 years, railroad; eight positions in 35 years, of which four years' experience was obtained before graduation.

(*f*) Graduate, 1905: Steel detailer, ½ year, fabricator; bridge designer, ½ year; bridge inspector, ½ year, railroad; bridge designer, 1 year, consulting engineer; steel checker, ½ year, fabricator; structural designer, ½ year, consulting engineer; bridge designer, 3½ years, municipality; building designer, 3 years, consulting engineer; consulting engineer, 3 years, self; naval designer, 1 year, fabricator; consulting engineer, 13 years, self; eleven positions in 27 years.

(*g*) Graduate, 1906: Draftsman and estimator, 7 years, fabricator; engineer of bridges, 7 years, municipality; Army, 2 years, Government; assistant chief engineer, 7 years, fabricator; chief engineer, 3 years, fabricator; five positions in 26 years.

(*h*) Graduate, 1907: Steel detailer, 6 years, fabricator; steel designer, 4 years, fabricator; Army, 2 years, Government; contracting agent, 9 years, fabricator; contracting manager, 4 years, fabricator; five positions in 25 years.

(*i*) Graduate, 1908: Structural draftsman, 5 years, fabricator; squad foreman, 3 years, fabricator; room engineer, 14 years, fabricator; plant engineer, 2 years, fabricator; four positions in 24 years.

(*j*) Graduate, 1912: Instrument man, 1 year; junior engineer, 1 year, Government; structural draftsman, 5 years, fabricator; squad foreman, 3 years, fabricator; bridge designer, 8 years, fabricator; in charge of bridge design 2 years, fabricator; six positions in 20 years.

(*k*) Graduate, 1914: Instrument man, 1 year, municipality; structural draftsman, 1 year, fabricator; bridge designer, 8 years; resident engineer, 4 years; bridge engineer, 4 years, railroad; five positions in 18 years.

The average length of service in each position is four years and ten months.

Drafting Department of a Structural Steel Company

A study was made of the conditions surrounding the employment situation in the drafting department of a structural steel fabricating company. The period covered in the analysis was from January 1, 1922, to January 1, 1932. The nature of the work is ordering material, detailing and checking shop drawings.

Number employed January 1, 1922, and engaged since then up to January 1, 1932	590	100 per cent
Remaining January 1, 1932	79	13 per cent
Resignations, all causes	511	87 per cent

TOTAL NUMBER OF RESIGNATIONS

Voluntary	363	63 per cent
Loaned out, engaged for summer only, transferred to other departments, men borrowed and returned	88	14 per cent
Laid off for lack of work	60	10 per cent

VOLUNTARY RESIGNATIONS

Better positions elsewhere	198	34 per cent
More compensation	34	6 per cent
To secure design experience	29	5 per cent
To take up contracting, teaching or business	37	7 per cent
To live near home of parents	22	4 per cent
To seek out-door work, ill health	7	1 per cent
Left for preferred out-door work	16	3 per cent
Inability or dislike for work	8	1 per cent
To return to college	12	2 per cent

Length of Service

Employed 10 years or more	36	6 per cent
Remaining less than one year	174	30 per cent
Remaining less than 3 months	54	9 per cent

Average length of service—590 men—3 years 3 months.

The technical education of the 590 men was received from the following sources:

American universities or colleges	382	65 per cent
Foreign technical schools	40	7 per cent
College students—non-graduates	12	2 per cent
Night schools and home studies	156	26 per cent

A large percentage of those who resigned voluntarily no doubt felt that they had secured sufficient experience in structural drafting to conform with their plans for varied experience before taking positions offering greater responsibility and compensation.

Those who resigned with less than three months' service did

not receive any benefit from their short service. Too many men resigned with less than one year's experience. It is generally conceded that a man should stay at least two years in structural drafting to the mutual advantage of himself and employer.

A small percentage belonged to the unfortunate class who were obliged to leave the drafting room because of ill health or who were incapable of doing the work or who disliked drafting. The latter were misplaced and did well to change to other vocations.

One Hundred Selected Engineers

The statement is frequently made of a successful engineer or one promoted that his success is merited or he is well qualified to fill the higher position. There is a correlation between the performances and qualifications of engineers. An analysis of this phase reaches back not only to the college days, but even penetrates into the high school days and home life for the determination of those influences shaping the destinies of engineers. A request in the form of questionnaires was made of American college graduates, seeking their opinions relative to the training and qualifications of engineers. One hundred replies were selected from about 125 received. Those accepted were preferably from the older graduates and those in positions of responsibility.

It is natural to expect that there would be different opinions, influenced principally by the differences in vocations, the varied college courses of recent date and a generation ago, and the personal equation. Some of the older graduates, it will be noted, suggested ideas which agree with the present plans of many colleges. There was no implication of criticism of the college courses as means to securing an education, but rather commendation of the achievements and the indispensability of colleges as a medium of training engineers.

Many of the engineers gave very thoughtful consideration to the questions asked. Their abilities, combined with many years of experience as a background, gave considerable weight to their replies. The one hundred engineers are graduates of thirty-nine universities and colleges. Twenty-three of these men have over twenty-five years of experience; twenty-one from twenty to twenty-five; eighteen from fifteen to twenty; eleven from ten to fifteen; twenty-five from five to ten; and two under five years. Classifying these men according to degree of responsibilities:

A. Administrative	0
B. Supervisory	12
C. In Charge	26
D. Routine	62
E. Sub-Engineering	0

Each of the five questions in the questionnaire is reported separately, with the replies given in the order of number of suggestions received. The various ideas conveying similar thoughts are combined under one heading, and the number of replies under each heading is given in parenthesis.

Some of the best opinions are quoted from the questionnaires to show the trend of thought. They are reported separately as (*a*), (*b*), (*c*), etc.

1. WHICH STUDIES HAVE BEEN MOST BENEFICIAL TO YOU IN YOUR WORK SINCE GRADUATION?

The replies in the order named are: Pure mathematics (78); mechanics (69); engineering design (44); mechanical drawing (30); English rhetoric and composition (29); theory of structures (28); strength of materials (28); reinforced concrete (21); physics (20); and economics (12).

Some named surveying, natural sciences, shop work, hydraulics, laboratory work, and masonry.

Several stated that all of their subjects were useful.

(*a*) As reflected in work, probably mechanics and structures, but considering the development of the mind, probably all studies had an important effect, so that I do not believe one to be more beneficial than another.

(*b*) Difficult to allow proper credit for studies taken even though they are not used knowingly in my line.

(*c*) Before entering college I had a number of years' experience on construction work, such as buildings, bridges and hydroelectric developments, and had been in charge of some large and highly important engineering work. My knowledge of design was limited to what I had acquired by self-study. I entered college to secure a better knowledge of the design of such structures I had been engaged upon. In college I was successful in securing the knowledge I desired, and this acquired knowledge enabled me to rise to the positions to which I aspired. Everything that I learned in college I found of value. There was no one study which I could say was of more value than the others.

2. WHICH STUDIES DO YOU CONSIDER HAVE BEEN APPARENTLY USELESS TO YOU IN YOUR WORK?

The studies in the order named are: Foreign languages (35); chemistry (24); boilers, gas, and steam engines (15); electricity (12); and shop work (12).

A number of engineers (24) stated that none of the studies was useless.

Some named hydraulics, calculus, economics, surveying, geology,

astronomy, roads and pavements, sewage and water supply, history, sanitary engineering, geodesy, and least squares.

(*a*) I was required to have six years of foreign languages. These six years of foreign languages have been absolutely useless. Geology might have been useful if it had been geology for engineers. College shop work is worse than useless.

(*b*) Calculus as taught.

(*c*) I doubt if any is useless when considered as mental development. Problems that are met and solved are not those found in text books, but are solved by the use of the mind.

(*d*) All studies have value. Foreign languages are least valuable. There is a value in securing a general college education even if not used in structural engineering work.

(*e*) None has been entirely useless, but some time was spent on chemistry and shop work that could have been used to better advantage otherwise.

(*f*) Economics as taught.

(*g*) I consider no study offered useless if it is conscientiously pursued.

(*h*) I do not believe in too much specialization in a four-year course.

3. CAN YOU SUGGEST ANY ADDITIONAL STUDIES WHICH YOU FELT WOULD HAVE BEEN OF ASSISTANCE TO YOU?

The majority of suggestions under this heading favored economics (63). The next in number were public speaking (33), and English rhetoric and composition (21).

Other suggestions named were cultural studies, psychology, practical calculus, structural design, shop practice, practical design, higher statics, indeterminate structures, steel erection, building construction, athletics, and vocational guidance.

(*a*) An engineering student should be required to take English composition four years. He should also be required to take public speaking and a short course in finance.

(*b*) Intensive training in practical problems in structural design and wider testing laboratory experience.

(*c*) Principles of finance for corporations, law as applied to liability and a more extensive course in law contracts.

(*d*) Public speaking and study of human relations.

(*e*) Business law, legal decisions relative to engineering problems, and business management.

(*f*) Engineering and business economics. Classical economics is of little value.

(*g*) More emphasis on public speaking; also on athletics.

(*h*) Any of several subjects, dependent upon the individual,

which develop his poise and ability to meet and to easily speak publicly.

(*i*) Public speaking, preferably in argumentation.

(*j*) More stress on economics, English, specifications, and contracts.

(*k*) English, rhetoric, economics, psychology, history, and in general any cultural studies.

(*l*) A more thorough treatment of engineering subjects.

(*m*) Accounting, public speaking, steel erection for bridges and buildings.

(*n*) Practical application of calculus.

(*o*) Cultural studies.

(*p*) I believe that more time should be spent on mathematical and pure scientific subjects and less time on trade subjects. Ability in the latter is readily acquired by one with good scientific knowledge.

(*q*) Vocational guidance, business law, accounting and stenography.

(*r*) Subjects treating with engineering economics. Subjects to develop self expression, so as to enable the engineer to impart his knowledge to others.

(*s*) Courses of general interest in life aside from the technical studies should have some place in the schools.

4. HAVE YOU ANY SUGGESTIONS IN REFERENCE TO NUMBER OF YEARS OF COLLEGE COURSE, METHODS OF TEACHING (LECTURES, RECITATIONS AND EXAMINATIONS) OR TIME DEVOTED TO EACH STUDY?

The largest number of suggestions (27) favored four years for the length of the college course. Nineteen suggested five years. There was a diversity of opinions of the distribution of studies over these periods.

Two thoughts prevailed throughout the replies, one that the fundamentals of mathematics and engineering (21) should be taught thoroughly and time devoted to the practical application of the fundamentals rather than advanced studies; the other that lectures (14) in the class room are academically less productive of results than recitations.

(*a*) Four years, provided entrance requirements are high enough.

(*b*) Four years in general engineering with provision for two years' special training and leading to C.E. degrees for those who can afford it.

(*c*) Four years are sufficient with less lectures than at present. The first three years should be given to general education, the fourth to the desired branch of engineering. Specializing will come after graduation.

(*d*) Four years should be sufficient. With the preparatory training that a boy gets in an up-to-date high school, it should be possible to take considerable time from the shop and laboratory schedule and apply it along lines of general business training without sacrificing any of the fundamentals of engineering. Some inducements should be offered to bring ambitious graduates back for advanced degrees after a few years of experience. A year in college then would be worth much more than the same time added at the end of the four-year course.

(*e*) More opportunity should be offered the student to gain an understanding of the usefulness of theory as applied to actual practice. This can be accomplished by close coöperation between large industrial and governmental bodies by establishment of some form of rotation of employment for students at nominal pay with such bodies. Experience obtained in this manner should become a part of every engineering course after the first two years of study which should consist of general preparation, after which the time spent in specializing becomes almost a necessity. Such an arrangement would of necessity increase the time of college work, but by eliminating the usual summer vacations nearly one year's time could be gained, and in this event four full years should be sufficient.

(*f*) Engineering should be a five-year course with more thought to practical engineering. The apprentice, or so-called coöperative course, is a good one.

(*g*) I should make five years the minimum elapsed time between matriculation and the college degree, conditioned so that the third or fourth year might be spent in professional work with pay.

(*h*) Three years of fundamentals, including English and public speaking; two years of application, including advanced courses, organization, financing, and management.

(*i*) Believe that six years should be spent on a well balanced engineering course. This should eliminate some from a crowded profession.

(*j*) As far as possible, recitations and examinations should be the general method of teaching. All structural engineering subjects should be taught by men who have had practical experience. There should be special stress in thoroughness of all mathematical courses and their practical application to engineering problems. The engineering course should be five years long.

(*k*) I would abolish examinations requiring the usual cramming merely to pass an examination; the system is wrong.

(*l*) I believe the universities of our country have a responsibility that does not end with teaching the student such facts as will be of value to him in his future business. We must depend largely upon our college graduates for our future leaders. A man should

function in his community more than merely as a wage earner. I, therefore, feel that a too highly specialized training for the masses may not be the best for the country. Even applied to engineering, there are so few engineers who know the type of work they are to follow, which in many cases is determined by luck and influences beyond their control, that they will be better equipped with a general engineering training, leaving for the future their more specialized training. Graduation is not the end but merely a step in his training. The university should give the fundamentals which are to serve as a foundation on which he must build his more specialized training.

(*m*) I suggest that visual instruction be given careful study—slides, movies, and sound pictures.

(*n*) I believe the student obtains the most benefit from recitations in the class room, with black board work. The classes at most universities are too large to permit personal contact between the student and his instructor.

(*o*) Recitations rigorously conducted for small sections with accompanying lectures, very long severe examinations with a low passing standard and limitation of the number of studies carried in accordance with the mental speed of the student.

(*p*) Reduce lectures to a minimum. Students should recite and work out problems. Frequent comprehensive quizzes and no final examinations.

(*q*) A permit to practice the profession should be required by all states. Engineers in subordinate positions should also be licensed.

(*r*) Would recommend more inspection trips to develop a sense of proportion and reality in students.

(*s*) The system of teaching mathematical courses could be improved. In fact, when one comes in contact with an engineer educated in a foreign country, the ease with which he uses his mathematics is noticeable.

(*t*) Most examinations are a test of a man's memorizing ability instead of his ability to apply the theories he has been studying.

(*u*) Laboratory work is the most impressive method of instruction.

(*v*) Think that too much emphasis should not be placed on any special course, such as structural, hydraulic, railroad or highway engineering. Would prefer same course for all civil engineers, and let them specialize after graduation. This will give a broader general knowledge.

(*w*) My only suggestion is that more problems taken from actual practice should be included in the engineering courses.

5. WHICH QUALIFICATION DO YOU CONSIDER OF MOST IMPORTANCE IN CONTRIBUTING TOWARD SUCCESS IN YOUR LINE OF WORK?

The many varied replies to this question are grouped under general headings for comparison.

Mental ability, variously termed clear thinking, concentration, analyzation, memory, imagination, initiative, judgment, observation, alertness, executive ability, and accuracy, was given in seventy replies as the most important qualification to success. Twenty-eight replies gave personality as the most important qualification, and a like number, knowledge. Twenty-one considered character; nineteen, industry; sixteen, the application of knowledge; thirteen, expression; twelve, technical training; eleven, interest in work; and eight gave health as the most important qualification.

(*a*) Eighty per cent personality, including responsibility in thought and action, mental energy, conscience, and pleasing manner. Twenty per cent experience and technical training.

(*b*) Native ability, absorbing interest and willingness, outside studying and reading, loyalty to employer, developing executive ability by assuming responsibility and keeping an open mind.

(*c*) Proficiency in mathematics, mechanics of material, principles of projection and perspective, physics, chemistry (as applied to engineering materials) and English language. One of the chief merits of English language study is the development of precision in expression and the ability to classify and organize information, so that it can be made useful to one's self or transmitted without impairment to others.

(*d*) Technically—Ability to adapt theoretical design to practical methods of fabrication and construction.

Generally—Winning and retaining the respect of others as to engineering ability and personal character.

(*e*) Knowledge of fundamentals and ability to continue to learn. Industry. Thrift. Ability to "sell" one's self and ideas.

(*f*) Honesty of purpose, sufficient interest in work to study and keep informed on all up-to-date practices and regularity of habits.

(*g*) Willingness to work, to do more than enough to get by.

(*h*) Being fortunate in getting into the right kind of an organization where there are opportunities for advancement.

Summation of Ideas

The numerous replies received expressed many diversified opinions; nevertheless, one is impressed with the unanimity of thought along certain lines. The engineers are in different vocations and were trained in different colleges at different periods, varying as much as twenty-five years, which naturally is reflected in the re-

plies. That which follows is a summation of the ideas prevailing throughout the questionnaires. It will be noted that the views do not differ greatly from existing college curricula, but on the contrary, many are in accord. The views are presented to emphasize their importance rather than their originality, for similar views have been presented in numerous papers and discussions.

Although home environment is the important medium for molding character, colleges have the responsibility of providing such influences as will counteract the temptations surrounding a boy when removed from parental care. Much good can be accomplished by supervision of the students' living quarters and the restrictions under which they live. This should be supplemented by a periodic investigation of public amusement places accessible to students for assurances as to their respectability.

The welfare and the physical training of students are also matters of vital importance. A course in physical training and hygiene under medical direction should be made compulsory throughout the collegiate course. The training should be primarily gymnasium work and such sports as swimming, tennis, base ball, basket ball foot ball, etc., elective. Provisions for good medical and hospital care greatly relieve the anxiety of parents and guardians.

College professors and instructors have the opportunity to observe the students who may be preparing for work for which they have no natural aptitude and for which they are not fitted. The teachers can perform a service of incalculable value to these students by a frank discussion of the students' plans and by wholesome advice. There are engineers in the wrong field to-day, who, in their proper spheres, might have become famous as surgeons, lawyers, financiers, or artists.

The majority of the replies indicated a preference for a four-year course leading to the degree of Bachelor of Science; and it is apparent that a general engineering course should take four years and such elective studies as desired may be taken during the fourth year. A post graduate course of one year should be optional and should confer the degree of Civil Engineer. An advanced degree should also be given to non-resident engineers after the fulfillment of prescribed requirements extending over a period of at least three years.

The classes should preferably be small in order to permit frequent recitation by the students and to allow closer contact with the instructors. Lectures are considered of little value compared with oral or black board recitations. The final examinations at the end of semesters cause cramming without permanent retention, and should be dispensed with. Grades should be based on the oral and black board recitations and drawing-board work, and quizzes should be given unannounced from time to time.

It is well known that engineers as a class are poor writers and speakers. Evidently these weaknesses are recognized by the engineers themselves, as many recommendations were made for extensive training in English and public speaking. The study of English, which should continue throughout the entire course, should include composition and the writing of letters and reports.

A foreign language is of assistance to many engineers in studying engineering developments in other countries and is a necessity to engineers entering foreign service.

Cultural studies are indispensable to a general education and are of the same value to engineers as to those of other professions. These studies should be given during the entire four years, as they require little time in preparation and class room.

The study of economics is conspicuously mentioned as important to the well balanced training of an engineer, and should be a general course with particular attention given to the divisions pertaining to engineering.

The subjects of pure science should be limited to elementary studies of chemistry, geology, astronomy, and physiography.

The study of physics furnishes the basis of engineering principles. The work in class room and laboratory should be very thorough.

The teaching of mathematics, mechanics, and kindred subjects should be limited to principles with practical applications. The fundamental principles should be thoroughly drilled into the students. It is of more importance to devote time to the fundamentals than to the solution of intricate problems which are soon forgotten. Calculus may be considered as an illustration of this point. The knowledge of calculus is essential in the derivation of formulas and in the solution of problems, yet few engineers can apply calculus. The principles should be so taught that calculus may be used with the same facility as algebra.

The course in design should deal with practical every-day problems, rather than with the unusual complex problems which are rarely met in actual practice. Instructors of design should, as far as possible, be men of practical experience in modern engineering.

The time devoted to surveying should be limited to the learning of rudimentary principles, since very few engineers have occasion to use their knowledge of surveying. Practice in the handling of instruments is easily acquired in actual experience.

There is a difference of opinion in regard to the advisability of teaching shop work in the colleges. Many engineers do not directly apply their knowledge of shop work, but nevertheless, it is useful indirectly to practically all engineers. For instance, detailers, designers, instructors, estimators, appraisors, consulting engineers,

and research engineers must be familiar with shop operations in their practice. This list comprises the great majority of those in the structural field. It seems advisable, therefore, to teach shop work in the engineering courses.

Many comments were made about the benefits derived by the students having practical experience before the end of the college course. This can be arranged by employment during vacation periods, and credit given therefore as a requisite for graduation.

The trips of inspection to industrial plants or works under construction, a policy followed by many universities, are considered as having a tendency toward broadness, and in many cases, seniors have found the inspection trips a means of contact in securing positions after graduation.

An engineer must continue his studies after graduation to keep pace with the developments and progress in his profession. The studies should consist not only in reviewing text books pertaining to his work but also in reading current engineering literature. Affiliation with and participation in the activities of one or more national technical societies is also advisable.

The professions of structural engineering and medicine are comparable in one respect, in so far as both safeguard human lives. They differ in another respect—the fatal errors of engineers are always uncovered. The motives for licensing physicians will apply equally well to engineers. Most states have license laws for structural engineers at the present time. The benefits of such laws would be enhanced if all the states had uniform laws with high standards governing the qualifications of applicants for licenses and reciprocal agreements permitting a licensed engineer in one state to practice or design work for construction in other states.

TECHNICAL EXPOSITION FOR THE GENERAL READER *

By JOHN MILLS

Director of Publication, Bell Telephone Laboratories

When the Director of your summer school proposed that I should speak on the subject which has been assigned to me I suggested that the title of my talk be "Styling an Engineering Idea" or preferably "What the Well-Dressed Technicality May Wear." The suggestion was rejected in favor of the present title.

This incident is mentioned not for its own importance but because it illustrates, I am afraid, the engineering attitude in exposition for the general reader. Whatever may be said in favor of entitling material completely and exactly for presentation to an engineering audience, uninterestingly exact titles will deter the general reader.

For such presentation I insist the idea must be styled. It must be carefully dressed in a manner suitable to its audience and attract favorable attention upon first glance. Its tone must be human, its coloring warm, and its mood varied, never monotonously heavy nor tiringly light, and certainly never drab. All of its accessories also must be in artistic harmony and should be skilfully devised since they may produce the more lasting impressions. Only when well dressed will the technicality have a chance of acceptance. The tailor's task is to dress the idea, for although the nude human figure may have appeal, the stark technical idea has none for a general audience.

Dressing a technicality is a work of literary art, creative in the same sense, whether or not to the same degree, as the scientific or engineering work which produced the idea itself. It must follow the same procedure of thought as any creative work—for only so will the resulting product be more than a mere mechanical assemblage of words, a presentation with the interest and emotional content of a specification.

The facts which the engineer has discovered are, to change the analogy, like nuggets and rock samples gathered by an explorer. Sound and intrinsically valuable although they may be, they must be mounted against a proper background, arranged for symmetry

* A lecture delivered at the English Session of the S. P. E. E. Summer School for Engineering Teachers, The Ohio State University, July 26, 1932.

and emphasis, and lighted for the display of their important characteristic features before they will attract more than passing attention from the general public. Only a part of the collection can be exhibited or else it will look like a rock pile: selection and ruthless elimination are demanded even if some of the explorer's most cherished specimens remain unexposed in their storage cases. Selection, arrangement, background and lighting constitute an artistic task which is too often beyond the talents of the explorer himself.

The exposition is a creative work, developed by processes of thought similar to those involved in any artistic production. (As a matter of fact the processes are also similar to those employed in any constructive, creative, or inventive thinking in science or engineering.) An analysis of the essential types of thought which most nearly conforms to my own observation and experience is that of Graham Wallas whose *Art of Thought* may well be read by every serious student of verbal expression.

Wallas is concerned with the *art* of thought as a modification by conscious effort of a "natural" form of behavior. To illustrate let us interrupt the present discourse by a pause of several seconds. . . . During the past few seconds each of us has had pass through his mind a train of ideas, mental pictures, or emotions—whatever you wish to call them; perhaps we have even engaged in silent dialogues. Each of us has been conscious of a train of ideas—an association train. This association of ideas is a natural process and it is Wallas's concern in this book to indicate how and at what stage in the process to bring conscious effort to bear.

As he says, if we examine a single achievement of thought we can distinguish four stages: preparation, incubation, illumination (with its earlier intimation) and verification.

At the preparation stage we consciously accumulate knowledge, divide up by logical rules the field of inquiry, and adopt a definite "problem attitude." For one engaged in technical exposition for the general reader this stage is one in which he first familiarizes himself thoroughly with the scientific material, if, as sometimes happens, he is describing engineering accomplishments other than his own. Next, to paraphrase Wallas's words, he considers logically the field of his activity, that is, technical exposition. He attempts to define for himself the audience which he wishes to address and to analyze his motives and necessities in reaching that audience—what, in other words, it is important to him that he transmit to the audience and conversely what are its instinctive interests and limitations. Knowing his material and with some ideas as to what he wants to effect, he now adopts a problem attitude. He wishes to determine: what aspect of the material shall be presented first to his audience? in what tone and style? and what then shall be the sequence?

That is what he wants to decide. He states the question to himself, adopts the problem attitude and enters upon the incubation stage. At this stage, as Wallas says, one can consciously arrange either to think on other subjects than the proposed problem or to rest from any form of conscious thought. The second form of incubation, he considers often necessary for the severer types of intellectual production which would be hindered either by interruption or by continuous passive reading. In the milder types, of which exposition is one, the necessary period of incubation can be spent at the wood pile, performing, physically or mentally, some familiar and repetitive task which neither involves nor admits of much external distraction.

Such an intuitive period of incubation must follow, for creative work, that of preparation, with its conscious, systematic and fruitless analysis. Whatever its duration, it terminates with intimations, from the trains of association which are forming, that solution of the problem is about to flash into consciousness. One feels, or knows, that he is on the verge of getting the idea he needs; his mind is ready for the task and tentative unsuccessful trains pass through it. There are faint intuitions and elusive ideas which vanish time and time again before, with a click, the happy idea arrives "without effort and like an inspiration." This is the stage of illumination, the shortest usually of all but, as far as originality of work or expression, the most important.

With the genesis of the idea from obscure actions of the subconscious, with the flash of illumination, the creative task is finished; and the thinker enters upon the fourth and last stage of Wallas's classification. This stage of verification, like the first of preparation, is a definite conscious activity where all the rules of logic apply. The idea must be studied and criticised, tried out and checked. If it fails of verification a successor may arise promptly from the subconscious, or a further period of incubation may be necessary—to be preceded perhaps by a rapid review stage of preparation.

For the expositor, illumination means ideas as to the order of presentation, the tone, and the keynote. The subsequent verification requires an actual arrangement of the words and paragraphs in an atmosphere of self criticism, both of details and ensemble. Ultimately verification is completed and the exposition, passing its final criticism, is accepted by its author.

In the usual run of scientific exposition the middle stages of incubation and illumination are missing; and the result is a stereotyped, but so-called logical, treatment without a spark of life or of emotional appeal—as attractive as the conventional newspaper caricature of the Dry Cause. A paper may be free from grammati-

cal error and uncouth expression, with its thoughts following in as formal a logical order as the terms of an arithmetical series, and yet be as ineffective as an automobile run out of gas. "There is no magic," as John Dewey said in *Democracy and Education*, "attached to material stated in technically correct scientific form." "Moreover," he continued, "this form of statement removes it further from fruitful contact with everyday experience than does the mode of statement proper to literature."

You may write for the engineer in the standard manner, if you wish, although, I believe, there are methods of exposition better adapted; but for the general reader you must attempt literature. When Theodore Roosevelt was preparing for his trip to South America a newspaper man, scanning the books he was taking, commented on the absence of any on science. "But science is so rarely literature," was the penetrating reply of the man who symbolized the average American of his time. It is true we have, or rather our English cousins do, our Jeans and Eddingtons but the writings of most of our eminent scientists and engineers are free from any taint of literature. This freedom is not for lack of inherent ability or low I.Q. but because the mind which takes naturally to science usually resents the idea that other than conscious processes may be responsible for its output; in fact, it scorns such intrusions of the subconscious as "hunches" to be deplored as dangerous engineering and the mechanism of the scientifically unsound. However intensely the scientist may wish to be creative in his work, he dreads creation in its exposition, although he thus limits his audience to those like minded.

In this he resembles his fellows in the older profession of law. An acquaintance of mine was adviser for a number of employee magazines, or house organs, in industries which were instituting a scheme of group insurance. Efforts were made to explain the provisions of the policies to the employees through articles in those magazines, but the articles had to be approved by the actuarial and legal departments of the insurance company. By the time the changes recommended by both departments had been incorporated in the manuscripts, the articles were identical in wording with the policies—and as unsuited for comprehension by the average employee.

The solution of the difficulty, as I see it, requires first a willingness to be as creative in exposition as in scientific work; next, the adoption of a problem attitude to determine along what line of interest, and how, to attract the reader; and finally, surrender without reservation to the creative potentialities of the subconscious mind.

The prospective reader is the author's student, although with the very loose nexus of an informal and transitory course of study.

What Dewey says of formal courses, however, applies: the method of instruction should be adopted which begins with the experience (for the present instance, let us say, interest) of the learner and develops from that the proper modes of treatment. This has been called the psychological method in distinction from the logical method of the expert. In the determination of the initial point of experience, or interest, and in the invention of modes of treatment, lie the opportunity and the necessity for creative effort by the teacher.

Why couch a message for the general reader in the style of a laboratory report with its divisions of object, method, experimental data, calculations and conclusions? Adopt rather the method of the novelist: plunge in medias res if that will attract, and let the story proceed from that point with such recapitulation of earlier events as may be essential for the reader—not for the author! Start anywhere except at the scientific beginning—wherever there may be smooth ground for the meeting of author and reader.

Each writer will develop his own technique. In my own case when the stage of intimation is set and a faint illumination seems in prospect, I am inclined to pace the floor of my office, talking to myself and forming the words which come into my head in hesitant speech to an unseen audience. If the phrases seem to fly and not fall flat; if my audience is with me and not against me, I have a start for my article and may settle down to pour it out to the typewriter. In later verification whole sections will be rejected, paragraphs rearranged, sentences reconstructed, and mayhap the entire manuscript recognized as a false start, relegated to the back of the desk drawer, and treated as a part of an extended stage of preparation which must be followed by more illumination.

Wherever one may start his exposition and whatever tricks he may try, to elicit the initiating ideas from his uncontrollable subconscious, I believe, he should follow a line of treatment which has due regard for the difficulty of his material to the comprehension of his readers.

The gradient of difficulty, that is the rate of its increase with succeeding pages of text, may facilitate or even inhibit the progress of the general reader. For the technician, on the other hand, the essentially uniform difficulty, typical of encyclopedia or treatise, proves most efficient. For the student in a formal course a favorable treatment will offer a difficulty which increases uniformly with successive chapters. The exposition, however, which is inexpertly arranged without regard to the relative comprehensibility of its parts is only too common. It is a disgrace to its author, an annoyance to its reader, and a glaring example of inefficiency.

None of these arrangements in terms of difficulty is suited to the

general reader, not even that of constant increase which is the method of the well constructed text book. Imparting technical information to such a reader ideally follows a sequence remarkably similar to that of the induction of magnetism in a bar of iron. When a magnetic force is applied and steadily increased the response of the iron takes place in three quite definite stages. At first it is very small indeed, as if the minute magnetic particles, or groups, within the iron resisted frictionally the new orientation which the magnetizing force would impose. Suddenly a condition is reached where a small increase in the force produces a relatively enormous increase in magnetism. For a time each succeeding increment of force causes a similarly large readjustment within the iron. Then, with the bar practically at the limit of its magnetizability—saturated, as it is called—the response becomes negligible. Further increase of force is unavailing.

Of similar stages and characteristics, I believe, is the induction of technical information in the mind of the general reader. The ideal treatment allows for such stages and proportions its difficulty accordingly. The exposition, therefore, should begin on a plane of zero technical difficulty for the prospective reader. This requirement is in addition to that previously mentioned of starting with an idea and in a manner interesting to the reader. The first part of the exposition is the stage for the formation of an acquaintanceship with the author and his material. If it is forced, intimacy may never be attained.

The friendship must be established on the reader's terms, not the author's. Technical material should be introduced gradually; too much information should not be supplied at the start; and the intercourse must be in a language easily understood. For myself I prefer to employ at this stage standard words of literary English which happen to have for the engineer additional and fitting scientific meanings. Examples from the preceding description of magnetization are "induction," "increment," "force," and "saturated."

The aim is a mild and insidious inoculation of the reader. In the second stage his mental system should undergo a rapid alteration as successive germ colonies bring their common efforts to bear. New concepts arise and each in turn facilitates the breakdown of his defenses and the orientation of his ideas along the compelling lines of the author's discourse. So far as concerns instruction of the reader the task is then well under way: he has acquired the proper point of view and can handle the most difficult material which the exposition demands. It can be supplied on that level throughout the third stage.

There remains for the author only the important decision as to when to quit.

APPENDIX

Since the subject of technical exposition for the general reader is of considerable social and economic importance, the manuscript of the preceding article was sent by Mr. Mills to seven men whose opinions on the subject would be of particular value. These men included the science writers of two important press associations; the editor of a widely known scientific news-service; the science editor of an important newspaper; the editor of an electrical trade magazine; an editor of a magazine of opinion; and a publisher of books of "more than ephemeral interest or value." Extracts made from their replies are here appended.

HOWARD A. BLAKESLEE, *Science Editor,* The Associated Press

"I have read your 'Technical Exposition for the General Reader,' and I would not change any of it. There are some minor points which I would like to emphasize.

"One is timeliness. That is an appeal which no form of writing can afford to miss. The reader wants to feel at first glance that here is something he ought to know now. . . .

"He wants to know 'What is it good for?' I do not think there are any exceptions, but that this unspoken question is universal. Engineers will recall that when Faraday discovered the principles of the dynamo Gladstone asked: 'What is it good for?' Faraday's reply is variously reported: 'Some day you can tax it,' or 'It is like a baby, some day it will grow up.' . . .

"Another point is extreme simplicity. The explanation of fundamentals necessary to make the mental picture may seem foolish to the technical man. And it is foolish unless the writer by hours of work, or by a flash of imagination, sees some phrase to make the old fundamental stand up in a new dress. If the new dress is a true picture, the result is good; if not true, it is just 'bunk.'

"I recall some of Elmer Sperry's phrases. For example, there has been much interest in the use of X-rays to examine strains in steel. Sperry called it 'looking through steel.' That phrase touched off the general reader's imagination. . . ."

LEIGH MATTESON, *Science Writer,* International News Service, Inc.

"As a professional reader of scientific papers and listener to science lectures, I heartily endorse the attempt of Mr. Mills to persuade scientists to come off technological high-horses whenever addressing the general public.

"But I would go even further. I would have them, for the convenience of the press of the country (and therefore the public), furnish along with all papers for publication, an abstract that sum-

marizes in understandable English the relation of their work to the general scientific problem involved, and explains the relation of that problem itself to life or industry.

"For the convenience of their busy colleagues, they now usually precede their published papers with a technical abstract which permits other scientists to estimate at a glance the importance of their work. But this importance is usually limited to the particular problems confronting scientists. . . .

"Certainly, if any scientific work is genuinely important, it is important for mankind as a whole, or for the large part of it, and it is extremely important that the work, its probable effect on living, thinking, feeling and future customs, and all details of the achievement which may stir human imagination, should be brought to the public as quickly and as completely as possible.

"Application of or benefit from any really great scientific discovery or achievement always waits on public interest, and the only means of arousing that interest is through publication or discussion of the work in popular terms. Most scientists of today seem to have forgotten, or never learned, that the elaborate laboratories in which they work, and the social esteem in which they are held, are due entirely to the interest produced not so many years ago in certain wealthy or socially prominent and then average people."

WATSON DAVIS, *Managing Editor,* Science Service

"The scientist or engineer who takes a 'public be damned' attitude in expressing the results of his research is like the architect who draws a beautiful edifice without regard for its use or the engineer who builds a structurally perfect building that is an eyesore on the landscape. Scientists and engineers are the architects and builders of our civilization. Their blueprints must be so clear and graphic that the public must enthuse over them and support their plans in preference to those of the jerry-builders who are always eager to snatch a contract. . . .

"Just as there are places in the order of things for the scientist who reviews the literature and points the problems without much original research, or the professor who passes on past knowledge catalytically to embryonic researchers, so the task of popularization must to a large degree rest with a relatively new sort of hybrid, part scientist, part journalist. I personally believe the parent stock of this hybrid should be the scientist, and the journalistic qualities can be grafted upon a fundamental feeling, appreciation and training for science or engineering. . . .

"Many current prejudices of exposition must be hacked away, within and without scientific and engineering circles. A newspaper headline and the more conservative type of a technical journal can carry equal amounts of truth. It will be a mistake if technical men scorn any effective medium of communication because others may have abused it. . . .

"A report of technical progress that satisfies the research worker because of its completeness and detail may actually be misleading for the same reason to the layman. . . .

"The technical popularizer must remember that the layman has little historical perspective in science and engineering and must often be carried through the fundamentals of past centuries and decades before he can understand today's achievements."

WALDEMAR KAEMPFFERT, *Science Editor, The New York Times*

"The engineer is not a successful expositor of his own work because he cannot forget that he must cease to be a technologist when he is writing for the general public and become an interpretative artist. . . . Style, then, reduces itself to the expression of a man—a peculiarly personal way of looking at a subject and therefore of interpreting it. It is a prime requisite in all scientific and engineering work that the personal be set aside. I think this is the reason why physicists and engineers find it so difficult to be interpretative artists. Their whole training is directed to the suppression of their personalities; and if personalities are suppressed, if emotional response is atrophied, there can be no art.

"Writing should be taught in a technical school not as an academic discipline but as an art. If an art is to be learned it must be practiced. . . . The student is saturated with technical facts, some of which he has been made to discover for himself. . . . Turn him loose, then, on the artistic interpretation of what he has been taught or what he has discovered. Let him see in how many different and appealing ways the same subject may be treated: and write not one essay but a half dozen essays. (1) A purely technical description . . . to a technically informed class of readers. (2) A simple description to arrest the attention of the technically uninformed public. (3) A vivid description of the social implications of the technical material—a 'work of literary art.' (4) A rhapsody in prose—a form that should be experimented with if the personality is to be taught how it may express itself freely.

"It may be objected that I am asking too much of the teacher of English—that he must himself be a first-class engineer in order to pass upon the writings of students who interpret what they have learned from professors of engineering. The demands on his knowledge will not be inordinate. After all we are concerned with style, creative art, rather than with technical accuracy of statement."

O. H. CALDWELL, *Editor, Electronics*

"Your complete presentation leaves nothing for me to add. But I am passing the proof around among the McGraw-Hill editors for their own benefit, as I feel sure your clear summary of principles and methods will do us all a lot of good here."

ROBERT MORSS LOVETT, *Editor, The New Republic*

"The scientist who writes for the general reader approaches his task with a viewpoint somewhat different from that of the strictly literary man. Many scientific writers regard this difference as a liability and strive to minimize it by attempting to make material palatable through liveliness of style. . . .

"The crux of the difference lies in the fact that with the writer whose profession is science more than with the writer whose profession is writing, the paramount interest is matter rather than manner. The professional writer is partially concerned with charming his audience. As a result, he often subordinates what he wants to say to the way he wants to say it, and this diversion of focus from substance to style introduces a meretricious quality which is partly responsible for the nauseous effect of much contemporary writing. On the other hand, complete absorption in material produces as a by-product stylistic results much happier than those achieved through direct preoccupation with style.

"This is not to minimize the importance of style, . . . but it must be a secondary rather than a primary product. If the subject in hand is thoroughly thought out, from the point of view of the writer, with due consideration for the limitations of the reader, the organization is bound to be satisfactory. . . . I have read semi-popular treatses on technical subjects, whose organization suggested that of a classic symphony in exposition, development, recapitulation—even in dramatic finale. . . . This beauty was achieved, not by striving for effect but by striving for accuracy. . . . It is therefore the more to be regretted that many scientists when they come to write for the lay public, through emulation of inferior writing or mistaken analysis of first rate writing, start at the wrong end.

"It may be objected that many scientists who have their subject thoroughly in command, write articles formless and deadly dull. The answer is that any sort of literary presentation demands an intensified perception of what one wishes to put across. It is not enough merely to understand it; one must feel it vividly, in its essence and its significance. One must, obviously, also take into account the limitations of his audience; but this is a question, not of organization or style, but of being explicit in reference; of not demanding too much from the reader. . . . This is a matter of conception rather than of execution; the prerequisite of intelligibility and simplicity is definiteness of thought. One of our greatest contemporary novelists has said, 'Style in writing as in painting, is a question of vision rather than of technique.' This is true in scientific writing as well as in so-called pure literature—assuming, as we have a right to assume, an adequate mastery of syntax and vocabulary. . . .

"It may be urged that the public will not take a pellet of information without an excess of sugar coating. The answer to that is,

then don't offer it! If the substance of the article is not of compelling interest, so that granted lucid form the public will want to read it, then there is no reason for trying to publish it. . . ."

ALFRED HARCOURT, Harcourt, Brace and Company, Inc., Publishers

"I read your 'Technical Exposition for the General Reader.' What you say is perfectly sound. I rather wish you had gone into the question of why scientific and technical men in this country often write so poorly. Unless they can get over certain inhibitions, your instructions or similar instructions will fall on deaf ears. Two reasons for their failure to write well occur to me. One is that some of them seem to think there is some lowering of scholarly or technical dignity in failing to write in the technical jargon and in making any concessions to the reader. . . . Another inhibition arises from a confusion as to their audience. Expository writers often want to reach the general public, but they do not keep their audience clearly in mind. They write with one eye cocked over their shoulder at what their colleagues in other universities may think of what they have to say, and so fail to cut loose for the general audience they have in mind."

WHAT DOES THE CONFIGURATIONIST SAY?*

By EARL BURT TAYLOR

Professor of Education, University of Rochester

As teachers we recognize that a science of the educational process must rest upon a science of psychology. We may apply scientific methods to a variety of problems related to education. But science in the learning process means psychology. We have been bewildered, and sometimes irritated, by the confusion which seems to reign in the psychological field.

The purpose of this discussion is to look into the views and claims of another "new" psychology said to be scientific and adequate to meet the objections raised against the conventional "objective" psychology. This is the *Gestalt* or "configurationist." We approach it in a spirit of skeptical tolerance. We are open to conviction but will not be "sold" easily. Cautious hopefulness is the keynote of our attitude.

The discussion will fall into four parts: the configurationist view of the learning process as explained by current objective psychology, the learning process as explained by the configurationist, an estimate of this "new" psychology, and the practical implications of the configurationist point of view applied to teaching. At the outset it should be said that we are somewhat limited by the literature available. Raymond Holder Wheeler and Robert Morris Ogden have been the chief interpreters of the configurationist psychology applied to education. We shall not be concerned primarily with criticism from the standpoint of pure psychology, which we are not competent to undertake. However, the teacher who is not a psychologist must look at psychology, whether or not he enjoys the view.

What does the configurationist think about conventional psychology? Nothing very complimentary, if we let Wheeler be his representative.† From the Greeks to Watson psychology has been dualistic and atomistic. The Greeks by structural analysis reduced the world to atoms; by functional analysis they reached mind.

* A paper based upon four lectures delivered before the English Session of the S. P. E. E. Summer School for Engineering Teachers held at The Ohio State University, July, 1932.

† Wheeler, Raymond Holder, "The Science of Psychology," pp. 20–23, 153–155, 261–267, 315–318; "The Laws of Human Nature," Chapters I and II and pp. 159–163.

Dualism and atomism have continued to the present time and represent the position of the "naïve psychologist" and the "naïve physical scientist." Under the influence of the epistemology of empiricism psychology developed associationism. This involved the false logic that unity is brought about from the chaos of atoms (sense-impressions, presentations, or bodily events), by the mysterious process of piece-meal building of whole through association fundamentally resting upon contiguity. This process of developing wholes as the additive outcome of associating parts or atoms became mechanistic. Then psychology had reached its present conventional dualistic form, atomistic, associationistic, mechanical. Behaviorism did not escape the traditional logic. ". . . he (Watson) accepted the conventional view that the activities of specialized parts of the organism account for the behavior of the organism-as-a-whole." * "Behaviorism followed the dualistic doctrine even more naïvely than introspectionism . . . (it) almost boastfully declared its repudiation of the mental life. It refused to work on the 'mind-side' of the fence." †

Conventional psychology rests upon the logical postulate that the whole is explained as the sum of its parts; the simple explains the complex. Unity is achieved by synthesis of atoms through association. That the atoms have changed in the course of time from sense-impressions and ideas to bodily events, reflexes, and stimulus-response connections does not modify the essential nature of the case. Combine this with dualism and mechanism, and we reach the heart of the modern psychology which dominates the field in education.

This dualistic, atomistic, associationistic, mechanistic, modern psychology attributes initial learning to chance success after application of the stimulus in a trial and error situation. Initial learning is reinforced by an inferred subjective condition in the learner. The experimenter does not know how it feels to be the rat who reaches the cheese after a long trip through a labyrinth, but he knows how he thinks he would feel about the blind alleys and other obstructive features of his trip. The rat, he thinks, concurs in this feeling and tends on repetition to avoid the turns which lead away from success and repeat those which lead toward it.

To learn it is necessary to be lucky in the first instance and depend mainly upon successive repetitions in which satisfaction and annoyance are positive or negative conditioning factors. The process is comprehended mainly in the Laws of Exercise and Effect. The more extreme objectivists, the behaviorists, drop the Law of Effect and rest the case more completely upon the Law of Exercise.

* Wheeler, Raymond Holder, "The Science of Psychology," p. 23.
† Wheeler, Raymond Holder, "The Laws of Human Nature," p. 41.

They make chance, repetition, and mechanical association of atomistic physical reflexes the fundamental principles of the learning process.

To the configurationist this is all wrong. His position may be understood in part by saying that it is a sweeping and categorical denial of what he regards as the fundamental principles of conventional psychology. He denies that the whole can be explained by the association or synthesis of parts. Nothing is learned about water by study of the properties of hydrogen and oxygen. He rejects trial and error, chance, pleasure and annoyance, and repetition as principles of learning. "It is evident that learning does not proceed by trial and error with accidental successes fixed by pleasure and errors eliminated by annoyance. . . . learning does not commence with random movements which are subsequently eliminated by mechanical agencies." * We do not learn by repetition, by doing. '. . . the concept (of repetition of response) . . . throws no light upon learning. . . . to assert that we learn by doing, or learn through exercise is as meaningless as to claim that we grow by living in time." †

Mechanism is unsound in several respects. It applies mathematics, a product of the human mind teleological in character, to the physical world and then assumes that the universe is mathematically mechanical. It employs the false method "of explaining the whole in terms of its parts." It assumes that parts are discrete elements, entities existing as such and in isolation, whereas it is common knowledge that all things exist only in relation to something else. It conceives of cause and effect relations between discrete things such that one discrete thing can act upon another discrete thing. Köhler ‡ contends that mechanical order is topographical, man-made, and limited in character. Conditions are created for the machine such that the sole directions in which forces may act are determined by the paths established topographically. The piston moves in the cylinder; it can not move freely. This kind of movement is radically different from the "play of actual forces" existing outside of the very limited field of man-made machines. In this broader situation "movement, (and) . . . direction and distribution of process (are) determined dynamically by interaction." § There is order, but it is non-mechanical in character.

We can get some insight into what a man believes by learning what he rejects. The configurationist rejects his interpretation of

* Wheeler, Raymond Holder, "The Science of Psychology," p. 316.
† Ibid., p. 323.
‡ Köhler, Wolfgang, "Gestalt Psychology," Chapter IV.
§ Köhler, Wolfgang, "Gestalt Psychology," pp. 134–135.

the principles of conventional psychology *in toto*. He accepts its experimental results, when not in conflict with his own, but reinterprets them in the light of his own principles.

What are the principles of the configurationist? What is his explanation of the learning process? What is a *gestalt*? These are difficult questions to answer. The configurationist view suffers from lack of adherents who can organize its materials and who possess the gift of clarity in exposition. The introduction of new terms and the new use of old terms do not simplify understanding.

Gestalt is no such trifle as merely another psychology. It is a new *Novum Organum* in the making. It is "the way out of a dead end" for psychology and science alike. It sets forth the principles of a new synthesis of universal knowledge. It is a rejection of the basic logic of all our mistaken thinking. The atomistic logic which creates unity out of chaotic elements by the synthesis of discrete atoms is one of the fundamentals in our misconceptions. Dualism is another. The configurationist gets rid of both, but he does it without becoming either a mechanist or a vitalist. At any rate he believes he does.

Both vitalism and mechanism postulate entities existing out of dynamic relations with each other. They can not get into relation to form a unity or a whole, save as the relation is dynamic. Mechanism brings in a "mysterious agent," creative synthesis, which "derives the properties of the whole from no source whatever, creates a unity out of whole cloth." * Mechanism tries to conceal the agent which established dynamic relations among parts to make unity by masking it in the words "creative synthesis." Vitalism is more honest about it, and postulates the agent openly. The configurationist abolishes the whole problem by asserting that dynamic relations among all parts exist from the beginning. No agent is necessary, mechanistic or vitalistic. It is not necessary to derive a unity that does not exist. The unity is always there. The factor which does not exist is the discrete part out of dynamical relation to all other discrete parts. It is simpler, aside from being true, to postulate that parts exist only when in dynamical relation to all other parts. That is, parts belong to dynamic wholes and do not exist out of that relation. Dynamic unity which does not permit the existence of discrete parts is always an organic whole.

The word *gestalt* is not the name of an entity or unit existing as a homogeneous ultimate part whence wholes are derived by bringing parts into relation. It is merely the name of the fundamental concept that parts are always in dynamical relation. It stands for the assumption that the concept of the organic whole is the solution of the whole puzzle. It is, therefore, the explanation, not some-

* Wheeler, Raymond Holder, "The Laws of Human Nature," p. 59.

thing to be explained. What we have is complex wholes dynamic in the organic sense. There are no discrete parts. The problem of getting unity out of plurality is solved, because there is no plurality in the usual meaning of the word. Energy exists in dynamic organic complex wholes. It exists in no other form. The name of this concept is *gestalt*.

We fell into our difficulties in thinking by confusion about structure and function. Structural analysis failed to explain, and the effort to explain function led to dualism. The difficulty vanishes when we think of structure and function as unity viewed differently. Structure is the static aspect of things; function is the dynamic aspect. Any event or change of movement is something happening. Structure is the something; function is the happening. Function is the active condition of structure. Structure is phenomenological; function gives structure its meaning. Structural analysis has its uses in aiding understanding, but fundamentally it does not explain. Explanation is to be found in functional analysis. By structural analysis we describe and classify. By functional analysis we explain. Structural analysis of a human being ends with the disappearance of the human being. Functional analysis of a human being investigates his activities as a human being.

The grand assumption of the configurationist is that the universe is an organic whole which is dynamic. It obeys the laws of dynamics. This is true of the universe as a whole. The universe as a whole includes every part of itself by definition. Hence every part of the universe, every event obeys those laws. One set of laws does for everything. Reality consists of energy systems interacting according to the laws of dynamics. The configuration is not an ultimate entity. It is an ultimate principle, a concept. It is the concept of unity as "an organized field of force." Structurally each bit of reality has its characteristic form or gestalt or configuration. Functionally it is a dynamic field, an organized system of energy. The configuration is the name of structure functioning in organized dynamic relations. It describes the ultimate. *It is not to be explained; it is the explanation.*

Proceeding from these assumptions the configurationist selects his basic laws of dynamics and applies them universally, to the learning process, to personality, to the social order, to everything. There are eight of these laws. Three of them may be comprehended in a single statement. ". . . *any item* of reality is in its own right an integrated whole that is more than the sum of its parts" . . . (Law of Field Properties) which "derive their properties from the whole" (Law of Derived Properties) which "conditions the activities of its parts" (Law of Determined Action).* Every en-

* Wheeler, Raymond Holder, "The Laws of Human Nature," pp. 71–78.

tity is an integrated whole not an integration of parts, but it is not a discrete entity. Just as each is a whole, each is a part of a larger whole until the concept of the universe as an integrated whole is reached. This is true whether the whole is an apple or an event in human behavior, however complex. *Every act of an organism is an integrated whole the first time it takes place.* Every bit of energy in the universe is a dynamic unity. Everything and every event are explained in terms of energy systems obeying dynamic laws.

The terms "goal" and "insight" are important for the configurationist. They are related to the Law of Least Action. This states that movement takes place along the shortest (or longest in optics) route in time. Action is defined as energy multiplied by time. This is related to the concept of potential. Before action can take place a difference of potential must exist. A point of "low stress" must precede action. It determines the direction of action necessary to resolve the stress; it is the goal. Thus a goal is established prior to all action whatever, organic or inorganic. The whole action is organized toward a goal, a point of low potential, before action begins. On the organic level this is described in the principle that every act of an organism, mental or overt, is an integrated whole *the first time it takes place.*

Insight is closely related to the idea of goal. Any action is an organization involving a goal, direction, and movement toward the goal along the line of least action. When the organism is at the level of conscious behavior, the organized response is insight. The criterion of insight is goal perception in situations involving new relations. The organism perceives the goal in the situation-as-a-whole or stimulus-pattern. Insight explains nothing. It is merely a word used as the name applied to what happens.

Here, we are told, the configuration is revealed as the concept of an organized field of force requiring no external agency to account for it, other than potential existing in dynamic relation to other potentials and without possibility of existence under other conditions. The configuration is the concept of *organized energy functioning within a system of differentials.* Consequently it always functions as an organized unit within a total situation requiring adjustment to differences in potential acting as disturbing factors. There can be as many kinds of configurations as there are kinds of energy systems.

Among biologic organisms all potentials are growth potentials. Maturation is a kind of growth resulting from organic interaction with environment. Stimulation is one of its major essentials. It is in the nervous system a differentiation of energy patterns the structural nature of which is unknown. Maturation is related to learning as growth is to the organic body. Physical growth takes place

in time, but time is not regarded as explanatory of growth. Learning takes place in repetition as growth takes place in time. Repetition of stimulation is "a non-explanatory condition, namely the temporal aspect of the learning process."* Stimulation leads to the kind of growth which is maturation. Time must be given to permit maturation to take place. Maturation is a condition of the structural basis of potentials leading to behavior according to the Law of Least Action. Maturation is something like a coiled spring except that it grows in the nervous system of a biologic organism and represents structural change the nature of which is not known.

The Law of Maximum Work holds that any disturbance (stimulus) of an organism affects the entire system, not merely the specific part disturbed. All the potential energies of the organism become kinetic. The organism-as-a-whole is mobilized to resist the disturbance or restore equilibrium. There is an "all-or-none" situation created the moment the balance of potentials is upset. Individual stimulus calling for individual response shooting through the organism as a telephone message goes through an exchange, without affecting the organism outside of the stimulus-response path is impossible and imaginary. Any stimulus is a stimulus to the whole organism.

The Law of Individuation governs the appearance of parts. From the atomistic point of view parts are primary, and wholes come into being through association of parts. The configurationist reverses this order. Parts emerge from wholes through processes of differentiation (the Law). From the undifferentiated movements of the infant, which are primary, come later skilled acts which are individuations evolved from the original mass movement as a whole. The principle holds through all learning and perception. The child seeing a face for the first time sees the whole face. He can not see its parts, eyes, nose, mouth. Gradually he differentiates until he can see omissions from the whole, note the lack of a nose in a pictured face. Finally he is able to recognize parts of the face apart from the whole from which the perceptions emerge. The eye has no meaning as a thing-by-itself. All parts are in some measure abstractions from wholes.

The fundamental position of the configuration is a denial of the evolution of wholes by synthesis of parts. This is made explicit in the Law of Field Genesis which states the implication of the entire position in the proposition that wholes evolve as wholes. This means that an individual in developing a skill does not add a specific as he improves. He increases the differentiation of his total behavior-pattern-as-a-whole. The ball player practicing curves does not add something to what he had before. The whole pattern of his action

* Wheeler, Raymond Holder, "The Science of Psychology," p. 323.

changes. The child learning to read does not add a word or phrase to his reading vocabulary. His whole behavior pattern changes. Oxygen and hydrogen can not be added to make water. The total energy pattern of a field of force is changed. It is neither addition nor synthesis of parts which is creative; it is the principle or organization. The difference between sugar and wood is not additive; it is organizational.

The Law of Configuration is in the nature of a summary. Discrete entities and discrete events do not exist; no isolated event or entity ever affects another isolated event or entity. No configuration exists by itself. It is always in relation to others. The universe is one big event comprehending and determining all others, the whole and every part being in a situation of relationship, dynamic in character. Reality is one continuous series of events. There are no simple events; all are complex. Reality is a great organized system of energy consisting of infinite energy systems all dynamically related to each other and to the determining whole. Mechanism and vitalism are solved problems. No external agent is required to explain movement.

Now we face the problem of estimating this total point of view. In this brief paper it is impossible to examine the sufficiency of its empirical foundations and its relation to scientific theory. Bruno Petermann * has done this at some length and in detail. His inquiry leaves him negative. What is it all, philosophy, science, psychology, or mythology?

If we have grasped the configurationist idea accurately, of which we are by no means certain, it seems to be saying over and over again that *structure has characteristic functions always in relation to total situations such that neither discrete structures nor discrete functions exist.* Space does not permit attention to the differences and discrepancies among its advocates. Wheeler † disposes of instinct as a "curious paradox." Koffka ‡ considering the technique displayed by apes in handling sticks suggests that putting small objects into holes may be instinctive. These differences are many and interesting. We have depended largely upon Wheeler for exposition because he has made the most complete attempts to get the whole view before us and has tried to give it some definiteness of meaning applied in teaching.

Excess of humility and over-suspension of judgment are not faults of this point of view. The assured fashion in which Wheeler disposes of age-long problems in a sentence or two or a few paragraphs is breath-taking to say the least. Mechanism, vitalism,

* "The Gestalt Theory and the Problem of Configuration."
† Wheeler, Raymond Holder, "Science of Psychology," p. 168.
‡ Reference by Ogden, R. M., "Psychology and Education," p. 273.

freedom, will, epistemology, do not detain him long. The view seems to mean that the configurationist has discovered the valid principles of all knowledge. It remains to apply them generally. It is a striking fact that the configurationist has not added so much to knowledge as to re-interpretation of knowledge, assuming that his interpretations are additions. He accepts the experimental results of all research, when not in conflict with his own, and interprets these results in terms of his theory. He is stronger in attack on conventional psychology than in making his own case. The comprehensive concept appears to be the organized character of energy into wholes each of which transcends its content in its principle of organization. Exactly what it means is not wholly clear. Suspension of final judgment until more evidence and exposition are available seems to be desirable. A clear exposition of the *gestalt* concept which assembled all its characteristics in one place and did not bring into the discussion everything in the universe, visible and invisible, would be a boon to the teacher who wants to have the foundation of psychological truth as a basis for his teaching, if psychological truth exists and if he can find out what it is.

When we turn to the application of the point of view to problems of teaching, we feel at home at once. It gives immediate aid and comfort to the teacher who knows that in every teaching situation he is obliged to face the child (organism-as-a-whole) in a situation-as-a-whole such that no amount of psychological abstraction or careful control succeeds in isolating a specific stimulus-response. The atomistic stimulus-response is easier to think with but practically impossible to set up in a real teaching situation. Educational theory has long held that we are teaching the child, the whole child, not abstract aspects of him. The idea goes back at least as far as Rousseau. The idea of stimulus-pattern and configurational-response appears descriptive of the actual situation.

The teacher is relieved and stimulated to be told that he and his students are not mere machines, that he is not a mechanic pushing psychological buttons and pulling psychological levers. But he wonders what it means when he finds that he is not essentially different from a gravitational system, that mind in an electro-magnetic field is, in principle, identical with mind in man, that mind is the same everywhere in the universe; "it is an instantaneous change in dynamic relations."* This "neutral dynamism" is not too clear.

The concepts of goal and insight are interesting when applied in teaching. Accidental success in trial and error situations is not a principle of learning.† We are pleased to know that in principle

* Wheeler, Raymond Holder, "Laws of Human Nature," p. 94.

† Wheeler, Raymond Holder: "Science of Psychology," p. 316. Yet

at least learning is intelligent behavior, the conscious perception of a goal to be reached in a new situation. In more complicated situations the relation of means to end is perceived, and tools are consciously used to reach the goal. Right action in learning takes place the first time, not by chance, but because perception and fixation of goal necessarily precede any action whatever. This kind of learning is a configurational response.

The definition of learning is attractive. Learning is the extension of individual insight into a particular situation and increase in the complexity of individual action in relation to a certain goal. Learning is growth of ability to perceive goals in new situations, together with the response consequent upon such perception. Progress is extending and strengthening insight. We do not learn by experience. We learn by insight into the experience we have. This is orderly but non-mechanical. It is deterministic, but the individual is a central and significant factor in the determinism. The individual, his goals or purposes, the total situation, the organized response perceived before action are the factors.

This sounds much like Mr. Dewey and the idea we have long had in educational theory. The teacher who wants to get the best results will try to have learning proceed along the lines of the learner's purposes or interests. It is a prime responsibility of the teacher to get the learner to share actively in the purposes of the learning. The end-in-view which is the learner's own, which develops the active "will to learn," is essential, if best results are to follow. The student must be motivated by perceiving the identity of his interest and the goal. Mr. Dewey has said that valid interest is the individual's identification of "the fact to be learned or action proposed with the growing self." * This induces educative or developing activities. Mr. Dewey concludes, "The problem of educators, parents, and the state is to provide the environment that induces educative or developing activities, and where these are found the one thing needful in education is secured." † The configurationist calls this thinking, conscious, purposeful, intelligent action for the achievement of a perceived goal.

When we consider the Law of Least Action as applied to the concept of maturation, we find again a close resemblance (at least verbal) to educational theory as expressed by Mr. Dewey. Maturation is a kind of growth the structural nature of which is not

accidental learning happens. How could it, if no action can ever take place except as a point of low potential appears in a field of force? Having learned with some difficulty that every act of an organism is an integrated whole before it begins, an organization having a goal determined by low stress and following least action, we wonder how accidental learning could ever take place.

* Dewey, John, "Interest and Effort in Education," p. 7.

† Ibid., p. 94.

known. Repetition is not a principle of learning; it is a time factor in the process. Maturation is stimulated externally. Consequently the significant factor in learning is repetition of the stimulus, or stimulus-pattern, not response. Maturation must have time to take place. Repetition of stimulus gives this time and also contributes directly to the process. This done the learned behavior follows according to the configurationist principle that every organic act is an integrated whole the first time it takes place. If this is correct, sheer drill should disappear from the educational process. Much repetition of stimulus-pattern should replace it. The spacing of repetitions is obviously more significant than the repetition itself because of the relation of repetition to maturation. Repetition is not eliminated; it is given a more significant place in the educational process.

With the concept of maturation before us we may summarize the learning process as the configurationist sees it. All learning is dependent upon the maturation level of the nervous system. A growth factor is a fundamental feature of the learning situation. Learning can not take place above the maturation level. New learning results when the presentation of a stimulus-as-a-whole, which is a stimulating situation, disturbs the equilibrium of the organism-as-a-whole. The disturbance leads to dislocation of nervous stresses. The total energy of the learner is mobilized under the Law of Maximum Effort. It is directed toward a point of "low potential" which is the perceived goal for the resolution of the stress. A new configuration is formed, perceptual-motor in character. The new behavior is fully integrated before it begins, and the new learning takes place the first time. Movement is toward the goal according to the Law of Least Action. The movement is the configurational-response. The total event is the interaction of the forces of the stimulus-pattern and the maturation level of the nervous system. When the configurational response occurs at the level of conscious action, the development of the response is described as the growth of insight. The significant factors for the teacher to comprehend and apply practically are involved in the terms stimulus-pattern, maturation, configurational-response, and insight. These are the configurationist substitutes for association and the building of learning by an additive process applied to atomistic units.

Putting all this into more usual language, learning is an active, dynamic process in which the learner is a direct participant, perceiving and following goals which he recognizes as identical with his own growth and upon which he willingly mobilizes his total resources of energy. The teacher's responsibility is to study the learner with a view to determining his present capacity to respond to the particular stimulating situation and set the stage so that the

situation may normally lead to the learning response, that is, so that the learner may grow in the direction of his developing insight. This is progress in intelligent behavior and describes the chief responsibility of the teacher in learning situations at every level.

If this "translation" truly represents the configurationist position, Mr. Dewey and most modern theorists in education would endorse its application, whatever reservations they might have respecting its foundations.

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The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

What Is Going On: Schumann at Columbia, Mann at Missouri Mines, French at Ohio State, Higbee at Iowa, are experimenting with the McCauley Test; French, Mann, and Schumann are also working on new plans of instruction looking toward the elimination of duplication, *i.e.*, "believing that students can pick up the use of instruments, inking . . . by working on theory problems," etc.; Mann and Schumann are collaborating in devising engineering aptitude tests; Otter at Ohio and Mann are devising ways of measuring "what learning the students actually have in drawing before any instruction takes place"; Rising at Purdue is experimenting with the teaching of drawing by means of moving pictures, is designing a ball-bearing draftsman's pencil sharpener, and is designing a testing machine for drawing instruments; Mann of Missouri recommends the construction of a "line gauge" to place before students a desirable standard for line widths and character; Iowa has introduced a new drawing course consisting of lectures and homework on advanced phases of general engineering drawing; McCully of Carnegie Tech is making a study to determine "how much mastery . . . is achieved by homework study, by lecture, by laboratory, . . . and whether repetition and elaboration of material presented in lecture is advancing the students' knowledge."

New Books.—Kirby of Yale is finishing a book on "The Early Years of Modern Civil Engineering." He has also published a report on motor vehicle accidents in Connecticut which contains charts of interest to teachers of drawing. Walsh of Oshkosh State Teachers College has published a Handbook of Perspective containing a new method. Field of Ohio State has published an introduction to Architectural Drawing. (What! no new book on Descriptive Geometry?)

Executive Committee: Chairman McCully has called a meeting of the Executive Committee of the Division of Engineering Drawing for the 22d and 23d of December at Purdue. The program for the 1933 meeting, plans for the 1933 competition in Engineering Drawing; a discussion of the progress on projects now being sponsored by the division, and other business of the division will claim the attention of the seven members who are planning to attend.

NEW MEMBERS

BARLOW, HOWARD W., Instructor in Aeronautical Engineering, University of Minnesota, Minneapolis, Minn. O. M. Leland, J. T. Akerman.

CHAPMAN, THOMAS G., Professor of Metallurgy, University of Arizona, Tucson, Ariz. G. M. Butler, James C. Clark.

CUNNINGHAM, JOHN B., Professor of Metallurgy, University of Arizona, Tucson, Ariz. G. M. Butler, James C. Clark.

DAHL, OTTO G., Professor of Electric Power Transmission, Massachusettts Institute of Technology, Cambridge, Mass. D. C. Jackson, W. H. Timbie.

DALEY, JOHN L., Instructor in Electrical Engineering, Yale University, New Haven, Conn. Chas. F. Scott, R. G. Warner.

DODGE, JOHN F., Professor of Petroleum Engineering, University of Southern California, Los Angeles, Calif. T. T. Eyre, P. S. Biegler.

DOWNARD, RICHARD W., Instructor in Mechanical Engineering, A. & M. College of Texas, College Station, Texas. F. C. Bolton, C. W. Crawford.

FOX, ROBERT M., Professor of Civil Engineering, University of Southern California, Los Angeles, Calif. P. S. Biegler, W. M. Wilson.

GLENN, BURDETTE, Assistant Professor of Civil Engineering, Oregon State College, Corvallis, Ore. G. W. Holcomb, H. S. Rogers.

HACKLEY, REGINALD A., Instructor in Electrical Engineering, Yale University, New Haven, Conn. Chas F. Scott, F. G. Warner.

JENSEN, ALFRED, Instructor in General Engineering, University of Washington, Seattle, Wash. F. M. Warner, E. R. Wilcox.

LONG, JAMES D., Assistant Professor of Agricultural Engineering, University of California, Berkeley, Calif. H. B. Walker, H. B. Langille.

MOCK, HARRY L., Assistant Professor of Mathematics, North Carolina State College, Raleigh, N. C. H. A. Fisher, John M. Foster.

SHERWOOD, WILLIAM W., Assistant Professor of Electrical Engineering, Yale University, New Haven, Conn. Chas. F. Scott, R. E. Doherty.

TARR, ALLAN L., Instructor in Chemical Engineering, Cooper Union, New York City. A. B. Newman, Geo. F. Bateman.

WAGNER, CARL L. H., Instructor in Mechanical Engineering, Purdue University, Lafayette, Ind. Geo. W. Munro, L. V. Ludy.

84 new members this year.

COLLEGE NOTES

Massachusetts Institute of Technology.—Under the direction of Professor R. S. Williams an investigation of the effects of nitrogen on steel is being carried on in the Institute research laboratories of Metallurgy. Extensixe X-ray studies are being carried on to determine whether the hardening effect of nitrogen is due to compounds of nitrogen with iron or aluminum, or both. Chemical analyses are also being made to determine the form in which nitrogen exists in a weld.

The ten-million volt electrostatic generator invented by Dr. R. S. Van de Graaff and now under construction in the Technology high-voltage laboratory at Round Hill should be complete by spring. This will make available a powerful weapon for assault on the nucleus of the atom. The apparatus is 43 feet high with aluminum spheres 15 feet in diameter within which the operatives will be perfectly safe even though the spheres carry a charge of millions of volts. The apparatus is supported on trucks running on rails 14 feet apart. Thus for very high voltage experiments corona effects with the metal frame of the roof can be avoided by running the entire apparatus out of doors.

Northeastern University.—The School of Engineering has completed an arrangement with the neighboring institution, the School of Education, Boston University, in which both schools will coöperate in the training of prospective teachers. In the past many graduates of the Northeastern University School of Engineering have accepted positions as teachers and administrators in high schools throughout New England. In view of the increasing importance of special training in the field of education for secondary school teachers, it seems highly desirable that candidates for the teaching profession not only have a thorough background in their subject-matter fields, but that they also be given some instruction in the art of teaching before entering the teaching profession.

On the plan which has been worked out by Dean Wilde of Boston University and Dean Ell of Northeastern, a limited number of selected students who desire to take up teaching as a life work will be appointed as Graduate Assistants upon their graduation from the five-year program at Northeastern University with the B.S. degree. These Graduate Assistants will give part time to the correction of papers and laboratory reports and to assisting in laboratory classes at Northeastern. They will give the rest of their time to graduate work in the field of education at Boston University and will be able to qualify for the degree of Master of Education at the

end of a two-year period, taking half of the usual program for graduate students each year.

The plan is very similar to the award of fellowships in many colleges and universities where graduates give part time to teaching and part time to the pursuit of graduate work for a higher degree, except that in this instance the work as Graduate Assistant will be done in one university and the class work for the graduate degree in another university.

Engineering at Yale.—The Yale School of Engineering has been established. The engineering faculty has been transferred from the Sheffield Scientific School to the new School. Professor R. E. Doherty has been appointed Dean of the new School and when Professor C. F. Scott, having reached the Yale age limit, retires at the end of the present year, Professor Doherty will be the head of the Electrical Engineering Department, as well as Dean.

Yale was one of the pioneers in science. Professor Benjamin Silliman was presumably the moving spirit which led to the appointment in 1846 of a Professor of Agricultural Chemistry and also a Professor of Practical Chemistry. The first graduate work in this country was inaugurated here and the first Ph.D. degrees were granted. Laboratory instruction was begun at about this time. In 1852 a Professor of Civil Engineering was appointed. The appointee, William A. Norton, wrote "I propose to open a School of Engineering." Later the Engineering and Applied Chemical Schools were included in a Scientific School. Later on the interest of Mr. Sheffield, a railroad and canal builder of the period, led to financial support and endowment and Yale gave the name "Sheffield Scientific School" to these activities. The fields of science, of applied science and of liberal education including scientific, economic, literary subjects and modern language (without the classics) constituted a marked innovation from the older ideas of college education as then found in Yale College and elsewhere.

The battle for the recognition of pure science as a legitimate part of a college curriculum was very largely fought and won by the men at the Scientific School at Yale. Professor S. W. Johnson was the father of agricultural chemistry and the first Agricultural Experiment Station was at the Scientific School. Here was established the first course in Mechanical, or Dynamic Engineering. Professor Brush was the father of Metallurgy and Dr. Chittenden of Physiological Chemistry. Francis A. Walker left the Scientific School faculty and became President of the Massachusetts Institute of Technology and Daniel C. Gilman of the Scientific School faculty became the first President of Johns Hopkins.

The Scientific School had a long, hard road to traverse to bring scientific and liberal education to full recognition. But it was suc-

cessful—in fact so successful that the scientific and educational ideals for which it contended are now accepted as matters of course. The whole University was reorganized a dozen years ago, as the old time distinction between the scientific and the classical, with separate and practically duplicate faculties in its two schools, was no longer a necessary or efficient type of organization.

Engineering departments developed in the Scientific School having basic science and fundamentals as the strong factor. It did not follow the practice of many schools and introduce shop work, and in fact laboratories, aside from chemistry and physics, did not appear until about twenty-five years ago.

The several engineering departments for some time past have been functioning together as a unit as a "Division" of the University. The recent step in recognizing them as an autonomous school is concisely set forth by President Angell in the following statement.

The Yale Engineering School

"The establishment of the Yale School of Engineering is a matter of greater significance than seems to have been generally recognized. The plan to take this step has been under consideration for a good many years, but hitherto the time has not been thought quite ripe for its consummation. Needless to say, it marks a somewhat belated compliance with what has for two or three generations been the prevalent American practice; for not only are there numerous engineering schools on entirely independent foundation, but it is also true that in every other American university except Yale, so far as I am aware, engineering has been organized under a separate faculty. All the implications of experience elsewhere therefore confirm our conviction that the new arrangement here will abundantly justify itself.

"The plan has long been urged by our graduates in engineering and it is launched with the cordial approval of the Sheffield Scientific School faculty, of the new University Division of Science, of the University Council and of the Corporation. It will accordingly have across its path no opposition within its own house.

"Professor Robert E. Doherty, who has been appointed Dean, upon the unanimous recommendation of the Engineering Faculty, brings to his new post a long and distinguished record in directing the educational program of one of the most progressive of the industries based on modern science. He is a scholar of established reputation in his special field and under his leadership of an unusually strong faculty, we may confidently look for immediate and steady advance in the development of the work of the new School.

"I may perhaps add, as is probably well understood, that the students in engineering will still receive the B.S. degree and will enjoy as at present all the privileges of other undergraduates."

SECTIONS AND BRANCHES

Kansas-Nebraska Section.—The Nebraska University group welcomed the first arrivals, the golfing contingency, at 11 o'clock A.M., October 28. Golf was played on the Shriner's course in the afternoon by some 15 or more visitors.

At 5 o'clock P.M. a visit to the Nebraska State Capitol building proved to be of great interest to the visiting members. After the tour of inspection all visiting members and ladies were the guests of the Nebraska members at a dinner served in the Capitol Cafe.

At 7:30 P.M., October 28, the evening meeting of the Society was held in Room 206, Mechanical Engineering Building. Prof. H. J. Kesner, chairman of the program committee, introduced T. Bruce Robb, Professor of Statistics and Business Research, University of Nebraska, who read a paper entitled "Forecasting the Railroad Future." Professor Robb's scholarly and erudite paper was well received by the Society, as was manifested by the eager discussion which followed its reading.

Prof. F. A. Russell of Kansas University opened the discussion. Among other members who commented at length in the discussion were Professors Hendricks of Nebraska University, Rice of Kansas University, Conrad and Mack of Kansas State, and Stewart of Iowa State.

President Hay appointed the following members as a nominating committee, to report at the business session in the morning:

Prof. C. A. Sjogren, Chairman, Nebraska University,
Prof. W. C. McNown, Kansas University,
Prof. R. M. Kerchner, Kansas State.

Adjournment was then had until 9 o'clock A.M., October 29.

Departmental Meetings

At 9 o'clock A.M., Saturday, Departmental meetings were held as follows:

Agricultural Engineers

The agricultural engineers met in Room 108 of the Agricultural Engineering Building with C. W. Smith, Nebraska University, as leader. A demonstration of teaching methods as practiced by the Agricultural Engineering Division at Nebraska University was given, with Prof. W. J. Runnalls conducting the shop demonstration, Prof. C. W. Smith, the testing demonstration, and Prof. E. B. Lewis on methods of conducting research.

Civil Engineers

The civil engineers' divisional meeting was held in Room 206, Mechanic Arts Building, with Prof. W. C. McNown of Kansas University as leader. A discussion was held regarding future practices and policies of the section. Topics under general discussion were, "Expanding the Section to include other neighboring universities"; "Increasing the number of annual meetings"; "Inviting the women to stay at home."

An interesting motion picture of Prof. C. E. Mickey's Summer Camp for civil engineering students was shown.

Applied Mechanics

Prof. F. L. Brown of Kansas University presided at the Applied Mechanics departmental meeting, held in Room 204, Mechanical Engineering Building. The topic of "Grading Home Problem Work" brought forth a lively discussion. Ideas were presented which ranged from the somewhat elaborate system of Prof. DeBaufre, Nebraska University, to the comparatively simple system of others. The relative weight of consideration given to final examinations, "shot guns," and daily work was discussed.

Electrical Engineers

The electrical engineers with Prof. R. G. Kloeffler, Kansas State, in charge, had an interesting meeting in Room 207, Mechanical Engineering Building. The topic chosen for disputation was "The Mechanics of Teaching." Personal ideas upon this subject were presented in speeches by Professors Eddison of Nebraska University, Jorgenson of Kansas State, and Warner of Kansas University, after which a roundtable discussion was freely indulged in, by virtually all of those present.

Mechanical Engineers

The mechanical engineers met in Room 206, Mechanical Engineering Building, Prof. W. F. Weiland, Nebraska University, was leader. The attention of the group was centered upon the subjects of "Heating and Ventilating Courses" and "Steam and Gas" laboratories.

The departmental meetings were well attended and those present participated freely in the discussions arising in the various groups. So interested did the Electrical Engineering group become in their discussions that they overstayed their time limit and coercion was almost necessary to get them to dissemble and attend the general

business meeting which convened in Room 206, Mechanical Engineering Building at 10:45 A.M. with Pres. Earl Hay presiding.

President Hay commended the Program Committee very highly for their efforts in outlining a meaty and entertaining programme. He stated that in his opinion the departmental meetings had been of unusual interest and wondered if they would be repeated at the next meeting.

The minutes of the 1931 meeting as reported by R. W. Warner, were read and approved.

An invitation was extended by President Hay to the Kansas-Nebraska Section to meet at Lawrence in 1933.

Professor Sjogren reported for the nominating committee, submitting the following recommendations:

For President—R. G. Kloeffler, Kansas State,
For Secretary—T. W. Norris, University of Nebraska,
For Chairman of Program Committee—John A. King, University of Kansas.

The report of the nominating committee was adopted and these men declared elected for the ensuing year.

A motion by Dean Ferguson, seconded by Prof. H. S. Beuche, in effect, that the Kansas-Nebraska Section accept the invitation of Kansas University for the meeting at Lawrence next year was carried.

Upon motion by Dean Seaton, which was seconded by Prof. A. J. Mack and unanimously carried, a rising vote of thanks was tendered to the Nebraska University members for their cordial hospitality and entertainment.

A motion prevailing that the retiring secretary be instructed to send a letter to Dean Shaad, then convalescent from an operation at Rochester, with the Section's greetings, best wishes, and hopes for a speedy recovery. (The wishes of the Section were transcribed by the secretary and posted to Dean Shaad upon adjournment of the business session.)

At the request of Dean Ferguson, our National President, R. A. Seaton of Kansas State spoke briefly. He reminded the section of the 41st annual meeting to be held in Chicago in June, 1933. He stated that at this time there will also be meetings of all of the Founder Engineering Societies, the National Council of State Boards of Engineering Examiners and the American Institute of Chemical Engineers. The S. P. E. E. will participate in Engineers' Day, a joint session of all engineering bodies to be held at the Century of Progress Exposition during the week including the 25th of June. President Seaton expressed his hopes for a large representation from this group at the Chicago meeting.

The Section was favored at this meeting by the attendance of 10 members from Iowa State at Ames. Prof. M. P. Cleghorn brought greetings from the Iowa group and extended a cordial invitation to all Kansas-Nebraska section members to visit them at Iowa.

B. B. Brackett of South Dakota University also attended the meeting.

Luncheon Meeting

All visiting members and ladies were the guests of the Nebraska group at a delightful luncheon in the Lincoln Chamber of Commerce.

Prof. E. D. Hay introduced the newly elected officers, President Kloeffler, Secretary Norris, and Programme Committee Chairman King. Each responded by gravely accepting with thanks, the responsibilities of office and promising to fulfil to the best of his abilities the duties imposed.

President Seaton spoke briefly, again mentioning the national meeting at Chicago June next. He gave it as his *conviction*, that the many good influences obtained from the association of the members of the Kansas-Nebraska section, had *spread abroad* and pointed to the newly organized sections of Arkansas-Oklahoma, Texas, Colorado-Wyoming, and sections in process of organization on the Pacific Coast as probable fruit of this influence.

Final adjournment was had at 1:25 P.M.

L. V. WHITE,
Secretary.

Kentucky Section.—Professor C. S. Crouse, head of the department of mines and metallurgy, University of Kentucky, was elected president of the Kentucky section of the Society.

He succeeds Prof. A. W. Homberger, head of the Department of Chemical Engineering of the University of Louisville.

Other officers chosen were H. H. Fenwick, Louisville, with the department of drawing of the University of Louisville, vice-president, and L. E. Nollau, head of the department of drawing of the University of Kentucky, secretary.

The next meeting of the section, which assembles twice annually, will be held at Louisville in April.

Approximately 30 engineering professors and associates from the two universities attended the meeting, which opened with a luncheon in the University Commons.

Speakers were Paul Morton, Lexington, city manager on the subject "Operating the City Manager Plan"; George W. Howson,

Lexington, chief engineer of the Kentucky Utilities Company, on "The Public Utilities Service."

The **Maine** Branch of the Society held a meeting in Merrill Hall, Tuesday, December 6, 1932. There were nineteen members present.

Dean G. D. Chase continued his talk of November 1, "Tutorial System and Comprehensive Examinations from European Viewpoint," and explained the English tutorial system as used at Oxford and the German Seminar system.

I. H. PRAGEMAN,
Secretary.

ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT

Seven national engineering bodies have organized the Engineers' Council for Professional Development with the announced objective of advancing the professional status of the engineer. The participating bodies and their representatives are:

American Society of Civil Engineers, J. Vipond Davies, Harrison P. Eddy, C. F. Loweth

American Institute of Mining and Metallurgical Engineers, Donald F. Irvin, D. H. McLaughlin, Benjamin F. Tillson

American Society of Mechanical Engineers, C. F. Hirshfeld, J. H. Lawrence, W. E. Wickenden

American Institute of Electrical Engineers, Charles F. Scott, C. O. Bickelhaupt, L. W. W. Morrow

American Institute of Chemical Engineers, H. C. Parmelee, A. B. Newman, John M. Weiss

Society for the Promotion of Engineering Education, Robert I. Rees, H. P. Hammond, Dugald C. Jackson

National Council of State Boards of Engineering Examiners, D. B. Steinman, T. Keith Legare, P. H. Daggett.

This new agency plans to coördinate and promote efforts directed toward higher professional standards. Its immediate objective is the development of a system whereby the progress of the young engineer toward professional standing can be recognized by the man himself, by the profession, and by the public through the development of those qualifications which render the engineer a valuable member of Society. It is believed that this will involve increased development along social, economic and general cultural lines as well as the maintenance of high technical standards of education and practice.

The Engineers' Council for Professional Development is embarking on a program of improving means for educational guidance of young men with respect to the engineering profession, the formulation of criteria for colleges of engineering, the determination of a program of personal and professional growth for young engineering graduates and the formulation of methods whereby engineers who have met suitable standards may receive corresponding professional recognition.

Four committees have been appointed to carry on this program. They are:

The Committee on Student Selection and guidance with Harrison P. Eddy, Consulting Engineer, Boston, Mass., as Chairman

The Committee on Engineering Schools with Dr. Karl T. Compton, President, Massachusetts Institute of Technology, as Chairman.

The Committee on Professional Training with Robert I. Rees, Assistant Vice-President, American Telephone and Telegraph Company, as Chairman

The Committee on Professional Recognition with Conrad N. Lauer, President Philadelphia Gas Works, as Chairman.

NECROLOGY

MORRIS KNOWLES

Morris Knowles was born October 13, 1869, and died November 8, 1932. He received the degree of S.B. from the Massachusetts Institute of Technology in 1891; Dr. of Engineering, University of Pittsburgh, in 1929. Mr. Knowles was employed by the Massachusetts State Board of Health, Water Commission, 1893–97; investigations design and construction of filtration systems and new water supply, Pittsburgh, Pa., 1897–1910; consulting engineering practice since 1903. He was President of Morris Knowles, Inc., and Director of Pittsburgh Aviation Industries Corp. He was also lecturer in Sanitary Engineering at the University of Pittsburgh.

Mr. Knowles had been a member of this Society since 1919 and had served as a member of the Council in 1921–4.

TINIUS OLSEN

Tinius Olsen, manufacturer and inventor, was born at Kongsberg, Norway, December 7, 1845, and died December 7, 1930. He was educated in the public schools of his native city and at the Technical School, Horten, Norway, maintained by the Norwegian navy. At the age of fifteen years he began his active career as a gun maker in the Kongsberg factory, and there early developed exceptional talent in mechanical construction. After his graduation at the Horten Technical School, in 1866, he became a machinist in the engine shops at the Horten navy yard. In 1868, he became foreman of a machine shop at Trondhjem, Norway, and, in the following year, availed himself of the offer made by the Norwegian government of subsidies. At first he went to England, but failing to obtain there the type of work which he desired, he decided to come to the United States. In 1869, he arrived in Philadelphia, and, at once, secured work as a draftsman in the large machine tool works of William Sellers. Mr. Olsen left the Sellers concern, and, since then, has devoted himself almost exclusively to devising and manufacturing scales and testing machinery of all types and for a wide range of purposes. Being a pioneer in this industry in the United States he found it necessary, in many instances, to design instruments and tools required in the manufacture of his testing machines.

Mr. Olsen has made numerous inventions, principally of testing apparatus, and some eighteen patents have been granted to him, the earliest in 1879. (National Cyclopedia of American Biography.)

BOOK REVIEWS

College Algebra. By H. P. Pettit and P. Luteyn. John Wiley and Sons, Inc., 1932; pp. 284.

It is both unusual and pleasant to turn back the introductory pages of a book on college algebra and find that the first chapter is not headed *Review*. To begin a semester's work in college algebra with a formal and extensive review of elementary algebra is anything but inspiring to the student and provides a rather boring time for the instructor. The authors of this book have tried to circumvent this situation by introducing immediately new material that is interesting and not too difficult—namely, the idea of a function and the summation convention. In the lists of exercises involving these two new ideas is incorporated a quite adequate review of elementary algebra, the advantage resulting that the review is restricted and purposeful instead of being the haphazard affair that it usually is. The graphical representation of functions is also introduced at the beginning of the text. The two new concepts, functions and graphs, are used repeatedly throughout the book with good effect.

Permutations and combinations are treated early in the course as is the idea of mathematical induction. The list of problems involving permutations and combinations is perhaps not as complete as this far-reaching subject warrants. The binomial theorem is proved by the theory of combinations with an alternative proof using mathematical induction. It is regrettable to find no treatment of the subject of probability which is undoubtedly the most fascinating of the applications of the theory of permutations and combinations.

Several modifications of the usual order of introduction of subject material are worth noting. Immediately upon the introduction of simultaneous equations in two variables the determinant notation is considered and subsequently developed fully. The study of exponents and logarithms is done consecutively, which seems a most logical and satisfactory procedure. The discussion of exponents is more complete that that usually given and includes a treatment of exponential functions. The interpolation of these functions is considered from a graphical standpoint; similarly, logarithmic interpolation is treated by a consideration of the logarithmic curve.

The discussion of quadratic equations is the usual one with the exception that no problems are given on the solution of quadratics

by completion of the square. This may be a justifiable omission but it seems that the proof of the quadratic formula would be better understood by the student if the method of completing the square had been applied to some particular equations before it is used in the case of the general quadratic.

Throughout the book, emphasis is placed on problems of a general nature—the solution of equations with literal coefficients, and the like. The ability to generalize is both powerful and useful and is rightly stressed here. A comparatively small number of the exercises are purely theoretical, the majority being applications to the sciences and to life experiences. The basic idea of the authors is that a knowledge of the symbols and operations of algebra is necessary, but that it is power in the use of this knowledge which is to be desired and this power can only be achieved after the repeated application of the well-known fundamentals to situations of widely varying natures.

THOMAS L. LAWSON.